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Application of PCT/JP00/04763

Akira YUMOTO

Serial No. **09/787,036**

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Examiner: L. Lao

Confirmation No. **8706**

For: CURRENT DRIVE CIRCUIT AND DISPLAY DEVICE USING THE SAME, PIXEL CIRCUIT, AND DRIVE METHOD

CERTIFIED TRANSLATION OF PRIORITY DOCUMENT

Commissioner of Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

The Applicant, through its representatives and attorneys, hereby brings to the attention of the Examiner an English language translation of Japanese Patent Appl. No. 11-200843.

The above-identified application is entitled to benefit of the filing date of Japanese Patent Appl. No. 11-200843. This Japanese Patent Application has a priority date of July 14, 1999.

Please take this English language translation into account in the examination of this application and make its consideration of record.

If the Examiner has any comments or suggestions that could place this application in even better form, the Examiner is requested to telephone Brian K. Dutton, Registration No. 47,255, at 202-955-8753 or the undersigned attorney at the below-listed number.

If any fee is required or any overpayment made, the Commissioner is hereby authorized to charge the fee or credit the overpayment to Deposit Account # 18-0013.

Respectfully submitted,

Date: February 10, 2004

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

APPLICANTS: Akira YUMOTO, Kanagawa, Japan

APPLICATION NO.: 09/787,036 Group Art Unit: 2673
FILING DATE: August 13, 2001 Examiner: Lao, Lun Yi
TITLE: CURRENT DRIVE CIRCUIT AND DISPLAY DEVICE USING SAME, PIXEL CIRCUIT, AND DRIVE METHOD
Hon. Commissioner for Patents,
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SIR;

CERTIFIED TRANSLATION

I, Shoji HIROSE, am an official translator of the Japanese language into the English language and I hereby certify that the attached comprises an accurate translation into English of Japanese Application No. 11-200843, filed on July 14, 1999.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

February 6. 2004 Shoji Hirose

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[TITLE OF THE INVENTION] Display Device

[Claim 1] A display device provided with

a scanning line drive circuit for successively selecting scanning lines,

a data line drive circuit including a current source for generating a signal current having a current level in accordance with brightness information and successively supplying the same to data lines, and

a plurality of pixels arranged at intersecting portions of the scanning lines and the data lines and including current driven type light emitting elements emitting light by receiving the supply of the drive current, wherein

each pixel comprises

a receiving part for fetching the signal current from a related data line when the related scanning line is selected,

a converting part for converting a current level of the fetched signal current to a voltage level and holding the same, and

a drive part for passing a drive current having a current level in accordance with the held voltage level through the related light emitting element.

[Claim 2] A display device as set forth in claim 1,

wherein

the converting part includes a conversion use insulating gate type field effect transistor provided with a gate, a source, a drain, and a channel and a capacitor connected to the gate and

the conversion use insulating gate type field effect transistor passes a signal current fetched by said receiving part to convert it and generate a voltage level at the gate and the capacitor holds the voltage level generated at the gate.

[Claim 3] A display device as set forth in claim 2, wherein

the converting part includes a switch use insulating gate type field effect transistor inserted between the drain and the gate of the conversion use insulating gate type field effect transistor,

the switch use insulating gate type field effect transistor becomes conductive when converting the current level of the signal current to the voltage level and electrically connects the drain and the gate of the conversion use insulating gate type field effect transistor to create the voltage level with the source as the reference at the gate, and

the switch use insulating gate type field effect transistor is cut off and separates the gate of the

conversion use insulating gate type field effect transistor and the capacitor connected to this from the drain when the capacitor holds the voltage level.

[Claim 4] A display device as set forth in claim 2, wherein:

said drive part includes a drive use insulating gate type field effect transistor provided with a gate, a drain, a source, and a channel, and

the drive use insulating gate type field effect transistor receives the voltage level held at the capacitor at its gate and passes a drive current having a current level in accordance with that through the light emitting element via the channel.

[Claim 5] A display device as set forth in claim 4, wherein the gate of the conversion use insulating gate type field effect transistor and the gate of the drive use insulating gate type field effect transistor are connected in series to configure a current mirror circuit and wherein the current level of the signal current and the current level of the drive current are proportional.

[Claim 6] A display device as set forth in claim 4, wherein the drive use insulating gate type field effect transistor is formed in the vicinity of the corresponding conversion use insulating gate type field effect transistor inside the pixel and has an equivalent

threshold voltage to that of the conversion use insulating gate type field effect transistor.

[Claim 7] A display device as set forth in claim 6, wherein the drive use insulating gate type field effect transistor operates in the saturated region and passes a drive current in accordance with a difference between the level of the voltage applied to the gate thereof and the threshold voltage through the light emitting element.

[Claim 8] A display device as set forth in claim 2, wherein

the drive part shares the conversion use insulating gate type field effect transistor together with the converting part in a time division manner, and

the drive part separates the conversion use insulating gate type field effect transistor from the receiving part and uses the same for driving after the conversion of the signal current is completed and passes the drive current to the light emitting element through the channel in a state where the held voltage level is applied to the gate of the conversion use insulating gate type field effect transistor.

[Claim 9] A display device as set forth in claim 8, wherein the drive part has a controlling means for cutting off an unnecessary current flowing to the light emitting element via the conversion use insulating gate

type field effect transistor at times other than the time of drive.

[Claim 10] A display device as set forth in claim 9, wherein the controlling means controls the voltage between terminals of a two-terminal type light emitting element having a rectification action to cut off the unnecessary current.

[Claim 11] A display device as set forth in claim 9, wherein

the controlling means comprises a control use insulating gate type field effect transistor inserted between the conversion use insulating gate type field effect transistor and the light emitting element, and

the control use insulating gate type field effect transistor becomes nonconductive in state and separates the conversion use insulating gate type field effect transistor and the light emitting element when the light emitting element is not driven and switches to the conductive state when the light emitting element is driven.

[Claim 12] A display device as set forth in claim 9, wherein the controlling means controls a ratio between a time for cutting off the drive current when the light emitting element is not to be driven and placing the light emitting element in the non-light emitting state

and a time of passing the drive current when the light emitting element is to be driven and placing the light emitting element in the light emitting and thereby to enable the control of the brightness of the pixel.

[Claim 13] A display device as set forth in claim 8, wherein the drive part has a potential fixing means for fixing the potential of the drain with reference to the source of the conversion use insulating gate type field effect transistor in order to stabilize the current level of the drive current flowing to the light emitting element through the conversion use insulating gate type field effect transistor.

[Claim 14] A display device as set forth in claim 1, wherein

the receiving part, the converting part, and the drive part configure a current circuit combining a plurality of insulating gate type field effect transistors, and

one or two or more insulating gate type field effect transistors have a double gate structure for suppressing current leakage in the current circuit.

[Claim 15] A display device as set forth in claim 1, wherein

the drive part includes an insulating gate type field effect transistor provided with a gate, drain, and

a source and passes the drive current passing between the drain and the source to the light emitting element in accordance with the level of the voltage applied to the gate, and

the light emitting element is a two terminal type having an anode and a cathode, where the cathode is connected to the drain.

[Claim 16] A display device as set forth in claim 1, wherein

the drive part includes an insulating gate type field effect transistor provided with a gate, a drain, and a source and passes a drive current passing between the drain and the source to the light emitting element in accordance with the level of the voltage applied to the gate, and

the light emitting element is a two terminal type having an anode and a cathode, where the anode is connected to the source.

[Claim 17] A display device as set forth in claim 1, further including an adjusting means for downwardly adjusting the voltage level held by the converting part and supplying the same to the drive part to tighten the black level of the brightness of each pixel.

[Claim 18] A display device as set forth in claim 17, wherein

the drive part includes an insulating gate type field effect transistor having a gate, a drain, and a source, and

the adjusting means downwardly adjusts the level of the voltage applied to the gate by raising the bottom of the voltage between the gate and the source of the insulating gate type field effect transistor.

[Claim 19] A display device as set forth in claim 17, wherein

the drive part includes an insulating gate type field effect transistor having a gate, a drain, and a source,

the converting part is provided with a capacitor connected to the gate of the thin film transistor and holding the voltage level, and

the adjusting means comprises an additional capacitor connected to that capacitor and downwardly adjusts the level of the voltage to be applied to the gate of the insulating gate type field effect transistor held at that capacitor.

[Claim 20] A display device as set forth in claim 17, wherein

the drive part includes an insulating gate type field effect transistor having a gate, a drain, and a source,

the converting part is provided with a capacitor connected to the gate of the insulating gate type field effect transistor on its one end and holding the voltage level, and

the adjusting means adjusts the potential of the other end of the capacitor when holding the voltage level converted by the converting part at that capacitor to downwardly adjust the level of the voltage to be applied to the gate of the insulating gate type field effect transistor.

[Claim 21] A display device as set forth in claim 1, wherein the light emitting element is an organic electroluminescence element.

[Claim 22] A pixel circuit for driving a current-driven type light emitting element arranged at an intersecting portion of a data line supplying a signal current of a current level in accordance with brightness information and a scanning line supplying a selection pulse and emitting light by the drive current, comprising

a receiving part for fetching the signal current from said data line in response to a selection pulse from said scanning line,

a converting part for converting a current level of the fetched signal current to a voltage level and holding the same, and

a drive part for passing a drive current having a current level in accordance with the held voltage level through the related light emitting element.

[Claim 23] A pixel circuit as set forth in claim 22, wherein

the converting part includes a conversion use insulating gate type field effect transistor provided with a gate, a source, a drain, and a channel and a capacitor connected to the gate and

the conversion use insulating gate type field effect transistor passes a signal current fetched by said receiving part to convert it and generate a voltage level at the gate and the capacitor holds the voltage level generated at the gate.

[Claim 24] A pixel circuit as set forth in claim 23, wherein

the converting part includes a switch use insulating gate type field effect transistor inserted between the drain and the gate of the conversion use insulating gate type field effect transistor,

the switch use insulating gate type field effect transistor becomes conductive when converting the current level of the signal current to the voltage level and electrically connects the drain and the gate of the conversion use insulating gate type field effect

transistor to create the voltage level with the source as the reference at the gate, and

the switch use insulating gate type field effect transistor is cut off and separates the gate of the conversion use insulating gate type field effect transistor and the capacitor connected to this from the drain when the capacitor holds the voltage level.

[Claim 25] A pixel circuit as set forth in claim 23, wherein:

said drive part includes a drive use insulating gate type field effect transistor provided with a gate, a drain, a source, and a channel, and

the drive use insulating gate type field effect transistor receives the voltage level held at the capacitor at its gate and passes a drive current having a current level in accordance with that through the light emitting element via the channel.

[Claim 26] A pixel circuit as set forth in claim 25, wherein the gate of the conversion use insulating gate type field effect transistor and the gate of the drive use insulating gate type field effect transistor are connected in series to configure a current mirror circuit and wherein the current level of the signal current and the current level of the drive current are proportional.

[Claim 27] A pixel circuit as set forth in claim 25,

wherein the drive use insulating gate type field effect transistor is formed in the vicinity of the corresponding conversion use insulating gate type field effect transistor inside the pixel and has an equivalent threshold voltage to that of the conversion use insulating gate type field effect transistor.

[Claim 28] A pixel circuit as set forth in claim 27, wherein the drive use insulating gate type field effect transistor operates in the saturated region and passes a drive current in accordance with a difference between the level of the voltage applied to the gate thereof and the threshold voltage through the light emitting element.

[Claim 29] A pixel circuit as set forth in claim 23, wherein

the drive part shares the conversion use insulating gate type field effect transistor together with the converting part in a time division manner, and

the drive part separates the conversion use insulating gate type field effect transistor from the receiving part and uses the same for driving after the conversion of the signal current is completed and passes the drive current to the light emitting element through the channel in a state where the held voltage level is applied to the gate of the conversion use insulating gate type field effect transistor.

[Claim 30] A pixel circuit as set forth in claim 29, wherein the drive part has a controlling means for cutting off an unnecessary current flowing to the light emitting element via the conversion use insulating gate type field effect transistor at times other than the time of drive.

[Claim 31] A pixel circuit as set forth in claim 30, wherein the controlling means controls the voltage between terminals of two-terminal type light emitting element having a rectification action to cut off the unnecessary current.

[Claim 32] A pixel circuit as set forth in claim 30, wherein

the controlling means comprises a control use insulating gate type field effect transistor inserted between the conversion use insulating gate type field effect transistor and the light emitting element, and

the control use insulating gate type field effect transistor becomes nonconductive in state and separates the conversion use insulating gate type field effect transistor and the light emitting element when the light emitting element is not driven and switches to the conductive state when the light emitting element is driven.

[Claim 33] A pixel circuit as set forth in claim 30,

wherein the controlling means controls a ratio between a time for cutting off the drive current when the light emitting element is not to be driven and placing the light emitting element in the non-light emitting state and a time of passing the drive current when the light emitting element is to be driven and placing the light emitting element in the light emitting and thereby to enable the control of the brightness of the pixel.

[Claim 34] A pixel circuit as set forth in claim 29, wherein the drive part has a potential fixing means for fixing the potential of the drain with reference to the source of the conversion use insulating gate type field effect transistor in order to stabilize the current level of the drive current flowing to the light emitting element through the conversion use insulating gate type field effect transistor.

[Claim 35] A pixel circuit as set forth in claim 22, wherein

the receiving part, the converting part, and the drive part configure a current circuit combining a plurality of insulating gate type field effect transistors, and

one or two or more insulating gate type field effect transistors have a double gate structure for suppressing current leakage in the current circuit.

[Claim 36] A pixel circuit as set forth in claim 22, wherein

the drive part includes an insulating gate type field effect transistor provided with a gate, drain, and a source and passes the drive current passing between the drain and the source to the light emitting element in accordance with the level of the voltage applied to the gate, and

the light emitting element is a two terminal type having an anode and a cathode, where the cathode is connected to the drain.

[Claim 37] A pixel circuit as set forth in claim 22, wherein

the drive part includes an insulating gate type field effect transistor provided with a gate, a drain, and a source and passes a drive current passing between the drain and the source to the light emitting element in accordance with the level of the voltage applied to the gate, and

the light emitting element is a two terminal type having an anode and a cathode, where the anode is connected to the source.

[Claim 38] A pixel circuit as set forth in claim 22, further including an adjusting means for downwardly adjusting the voltage level held by the converting part

and supplying the same to the drive part to tighten the black level of the brightness of each pixel.

[Claim 39] A pixel circuit as set forth in claim 38, wherein

the drive part includes an insulating gate type field effect transistor having a gate, a drain, and a source, and

the adjusting means downwardly adjusts the level of the voltage applied to the gate by raising the bottom of the voltage between the gate and the source of the insulating gate type field effect transistor.

[Claim 40] A pixel circuit as set forth in claim 38, wherein

the drive part includes an insulating gate type field effect transistor having a gate, a drain, and a source,

the converting part is provided with a capacitor connected to the gate of the thin film transistor and holding the voltage level, and

the adjusting means comprises an additional capacitor connected to that capacitor and downwardly adjusts the level of the voltage to be applied to the gate of the insulating gate type field effect transistor held at that capacitor.

[Claim 41] A pixel circuit as set forth in claim 38,

wherein

the drive part includes an insulating gate type field effect transistor having a gate, a drain, and a source,

the converting part is provided with a capacitor connected to the gate of the insulating gate type field effect transistor on its one end and holding the voltage level, and

the adjusting means adjusts the potential of the other end of the capacitor when holding the voltage level converted by the converting part at that capacitor to downwardly adjust the level of the voltage to be applied to the gate of the insulating gate type field effect transistor.

[Claim 42] A pixel circuit as set forth in claim 22, wherein the light emitting element is an organic electroluminescence element.

[Claim 43] A method of driving a light emitting element for driving a current-driven type light emitting element arranged at an intersecting portion of a data line supplying a signal current of a current level in accordance with brightness information and a scanning line supplying a selection pulse and emitting light by the drive current, comprising

a receiving routine for fetching the signal current

from said data line in response to a selection pulse from said scanning line,

a converting routine for converting a current level of the fetched signal current to a voltage level and holding the same, and

a drive routine for passing a drive current having a current level in accordance with the held voltage level through the related light emitting element.

[Claim 44] A method of driving a light emitting element as set forth in claim 43, wherein

the converting routine includes a routine using a conversion use insulating gate type field effect transistor provided with a gate, a source, a drain, and a channel and a capacitor connected to the gate and

in the routine, the conversion use insulating gate type field effect transistor passes a signal current fetched by said receiving part to convert it and generate a voltage level at the gate and the capacitor holds the voltage level generated at the gate.

[Claim 45] A method of driving a light emitting element as set forth in claim 44, wherein

the converting routine includes a routine using a switch use insulating gate type field effect transistor inserted between the drain and the gate of the conversion use insulating gate type field effect transistor,

in the routine, the switch use insulating gate type field effect transistor becomes conductive when converting the current level of the signal current to the voltage level and electrically connects the drain and the gate of the conversion use insulating gate type field effect transistor to create the voltage level with the source as the reference at the gate, and

the switch use insulating gate type field effect transistor is cut off and separates the gate of the conversion use insulating gate type field effect transistor and the capacitor connected to this from the drain when the capacitor holds the voltage level.

[Claim 46] A method of driving a light emitting element as set forth in claim 44, wherein:

said drive routines includes a routine using a drive use insulating gate type field effect transistor provided with a gate, a drain, a source, and a channel, and

in the routine, the drive use insulating gate type field effect transistor receives the voltage level held at the capacitor at its gate and passes a drive current having a current level in accordance with that through the light emitting element via the channel.

[Claim 47] A method of driving a light emitting element as set forth in claim 46, wherein the gate of the conversion use insulating gate type field effect

transistor and the gate of the drive use insulating gate type field effect transistor are connected in series to configure a current mirror circuit and wherein the current level of the signal current and the current level of the drive current are proportional.

[Claim 48] A method of driving a light emitting element as set forth in claim 46, wherein the drive use insulating gate type field effect transistor is formed in the vicinity of the corresponding conversion use insulating gate type field effect transistor inside the pixel and has an equivalent threshold voltage to that of the conversion use insulating gate type field effect transistor.

[Claim 49] A method of driving a light emitting element as set forth in claim 48, wherein the drive use insulating gate type field effect transistor operates in the saturated region and passes a drive current in accordance with a difference between the level of the voltage applied to the gate thereof and the threshold voltage through the light emitting element.

[Claim 50] A method of driving a light emitting element as set forth in claim 44, wherein

the drive routine shares the conversion use insulating gate type field effect transistor together with the converting part in a time division manner, and

the drive routine separates the conversion use insulating gate type field effect transistor from the receiving part and uses the same for driving after the conversion of the signal current is completed and passes the drive current to the light emitting element through the channel in a state where the held voltage level is applied to the gate of the conversion use insulating gate type field effect transistor.

[Claim 51] A method of driving a light emitting element as set forth in claim 50, wherein the drive routine includes a control routine for cutting off an unnecessary current flowing to the light emitting element via the conversion use insulating gate type field effect transistor at times other than the time of drive.

[Claim 52] A method of driving a light emitting element as set forth in claim 51, wherein the control routine controls the voltage between terminals of two-terminal type light emitting element having a rectification action to cut off the unnecessary current.

[Claim 53] A method of driving a light emitting element as set forth in claim 51, wherein

the control routine is a routine using a control use insulating gate type field effect transistor inserted between the conversion use insulating gate type field effect transistor and the light emitting element, and

in the routine, the control use insulating gate type field effect transistor becomes nonconductive in state and separates the conversion use insulating gate type field effect transistor and the light emitting element when the light emitting element is not driven and switches to the conductive state when the light emitting element is driven.

[Claim 54] A method of driving a light emitting element as set forth in claim 51, wherein the control routine controls a ratio between a time for cutting off the drive current when the light emitting element is not to be driven and placing the light emitting element in the non-light emitting state and a time of passing the drive current when the light emitting element is to be driven and placing the light emitting element in the light emitting and thereby to enable the control of the brightness of the pixel.

[Claim 55] A method of driving a light emitting element as set forth in claim 50, wherein the drive routine includes potential fixing routine for fixing the potential of the drain with reference to the source of the conversion use insulating gate type field effect transistor in order to stabilize the current level of the drive current flowing to the light emitting element through the conversion use insulating gate type field

effect transistor.

[Claim 56] A method of driving a light emitting element as set forth in claim 43, wherein

the receiving routine, the converting routine, and the drive routine are executed on a current circuit combining a plurality of insulating gate type field effect transistors, and

one or two or more insulating gate type field effect transistors have a double gate structure for suppressing current leakage in the current circuit.

[Claim 57] A method of driving a light emitting element as set forth in claim 43, wherein

the drive routine is performed using an insulating gate type field effect transistor provided with a gate, drain, and a source and passes the drive current passing between the drain and the source to the light emitting element in accordance with the level of the voltage applied to the gate, and

the light emitting element is a two terminal type having an anode and a cathode, where the cathode is connected to the drain.

[Claim 58] A method of driving a light emitting element as set forth in claim 43, wherein

the drive routine is performed using an insulating gate type field effect transistor provided with a gate, a

drain, and a source and passes a drive current passing between the drain and the source to the light emitting element in accordance with the level of the voltage applied to the gate, and

the light emitting element is a two terminal type having an anode and a cathode, where the anode is connected to the source.

[Claim 59] A method of driving a light emitting element as set forth in claim 43, further including an adjusting routine for downwardly adjusting the voltage level held by the converting routine and supplying the same to the drive routine to tighten the black level of the brightness of each pixel.

[Claim 60] A method of driving a light emitting element as set forth in claim 59, wherein

the drive routine includes uses an insulating gate type field effect transistor having a gate, a drain, and a source, and

the adjusting routine downwardly adjusts the level of the voltage applied to the gate by raising the bottom of the voltage between the gate and the source of the insulating gate type field effect transistor.

[Claim 61] A method of driving a light emitting element as set forth in claim 59, wherein

the drive routine uses an insulating gate type field

effect transistor having a gate, a drain, and a source,

the converting routine uses a capacitor connected to the gate of the thin film transistor and holding the voltage level, and

the adjusting routine uses an additional capacitor connected to that capacitor and downwardly adjusts the level of the voltage to be applied to the gate of the insulating gate type field effect transistor held at that capacitor.

[Claim 62] A method of driving a light emitting element as set forth in claim 59, wherein

the drive routine uses an insulating gate type field effect transistor having a gate, a drain, and a source,

the converting routine uses a capacitor connected to the gate of the insulating gate type field effect transistor on its one end and holding the voltage level, and

the adjusting routine adjusts the potential of the other end of the capacitor when holding the voltage level converted by the converting routine at that capacitor to downwardly adjust the level of the voltage to be applied to the gate of the insulating gate type field effect transistor.

[Claim 63] A method of driving a light emitting element as set forth in claim 43, wherein the light

emitting element is an organic electroluminescence element.

[Claim 64] A display device including:

scanning lines for selecting pixels and data lines giving brightness information for driving the pixels arranged in a matrix,

each pixel including a light emitting element changing in brightness by an amount of current supplied, a writing means controlled by a scanning line and writing in the pixel brightness information given from the data line, and a drive means for controlling the amount of current supplied to said light emitting element in accordance with the written brightness information,

the brightness information being written in each pixel by applying an electric signal based on the brightness information to the data line in the state with the scanning line selected,

the brightness information written in each pixel being held in each pixel even after the scanning line is not selected and the light emitting element of each pixel able to remain lighted by a brightness in accordance with the held brightness information, further comprising

an adjusting means for downwardly adjusting the brightness information written by said writing means and supplying the same to said drive means to tighten the

blackness level of each pixel.

[Claim 65] A pixel circuit for driving a pixel having a light emitting element arranged at an intersecting portion of a data line supplying brightness information and a scanning line supplying a selection pulse and emitting light in accordance with said brightness information, including

a writing means controlled by a scanning line and writing in the pixel brightness information given from the data line and a drive means for controlling the amount of current supplied to said light emitting element in accordance with the written brightness information,

the brightness information being written in each pixel by applying an electric signal based on the brightness information to the data line in the state with the scanning line selected,

the brightness information written in each pixel being held in each pixel even after the scanning line is not selected and the light emitting element of each pixel able to remain lighted by a brightness in accordance with the held brightness information, further comprising

an adjusting means for downwardly adjusting the brightness information written by said writing means and supplying the same to said drive means to tighten the blackness level of each pixel.

[Claim 66] A method of driving a display device including scanning lines for selecting pixels and data lines giving brightness information for driving the pixels arranged in a matrix, each pixel including a light emitting element changing in brightness by an amount of current supplied, comprising:

a writing routine controlled by a scanning line and writing in the pixel brightness information given from the data line and a drive routine for controlling the amount of current supplied to said light emitting element in accordance with the written brightness information,

the brightness information being written in each pixel by applying an electric signal based on the brightness information to the data line in the state with the scanning line selected,

the brightness information written in each pixel being held in each pixel even after the scanning line is not selected and the light emitting element of each pixel able to remain lighted by a brightness in accordance with the held brightness information, further comprising

an adjusting routine for downwardly adjusting the brightness information written by said writing routine and supplying the same to said drive routine to tighten the blackness level of each pixel.

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[Technical Field of the Invention]

The present invention relates to a display device providing for each pixel an organic electroluminescence (EL) element or other light emitting element controlled in brightness by a current. In more detail, it relates to a so-called active matrix type image display device controlled in the amount of current supplied to the light emitting element by an insulating gate type field effect transistor or other active element provided in each pixel.

[0002]

[Prior Art]

In general, in an active matrix type image display device, an image is displayed by arranging a large number of pixels in a matrix and controlling a light intensity for every pixel in accordance with given brightness information. When using a liquid crystal as an electro-optical substance, the transmittance of each pixel varies in accordance with a voltage written into the pixel. In an active matrix type image display device using an organic electroluminescence material as the electro-optical substance as well, the basic operation is similar to that of the case where a liquid crystal is used. However, unlike a liquid crystal display, an

organic EL display is a so-called self-luminescent type having a light emitting element for every pixel, so has the advantages of a better visual recognition of the image in comparison with a liquid crystal display, no need for back light, and a fast response speed. The brightnesses of individual light emitting elements are controlled by the amount of current. Namely, this display is largely different from a liquid crystal display in the point that the light emitting elements are current driven types or current controlled types.

[0003]

In the same way as a liquid crystal display, in an organic EL display as well, there are a simple matrix and an active matrix drive methods. The former is simple in structure, but makes it difficult to realize a large sized, high definition display, so the active matrix method is being vigorously developed. The active matrix method controls the current flowing through the light emitting element provided in each pixel by an active element (generally a transistor, one type of the insulating gate type field effect transistor, hereinafter sometimes referred to as a "TFT") provided inside the pixel. An organic EL display of this active matrix method is disclosed in for example Japanese Unexamined Patent Publication (Kokai) No. 8-234683. One pixel's worth of an

equivalent circuit is shown in Fig. 1. The pixel is comprised of an organic light emitting element OLED, a first thin film transistor TFT1, a second thin film transistor TFT2, and a holding capacitor C. The light emitting element is an organic electroluminescence (EL) element. An organic EL element has a rectification property in many cases, so is sometimes referred to as an OLED (organic light emitting diode). In the figure, the symbol of a diode is used to indicate the light emitting element OLED. However, the light emitting element is not always limited to an OLED and may be any element controlled in brightness by the amount of the current flowing through it. Also, a rectification property is not always required in the light emitting element. In the illustrated example, a source of the TFT2 is set at a reference potential (ground potential), an anode of the light emitting element OLED is connected to Vdd (power supply potential), and a cathode is connected to a drain of the TFT2. On the other hand, a gate of the TFT1 is connected to a scanning line SCAN, the source is connected to a data line DATA, and the drain is connected to the holding capacitor C and the gate of the TFT2.

[0004]

In order to operate the pixel, first, when the scanning line SCAN is brought to a selected state and a

data potential Vw representing the brightness information is applied to the data line DATA, the TFT1 becomes conductive, the holding capacitor C is charged or discharged, and the gate potential of the TFT2 coincides with the data potential Vw. When the scanning line SCAN is brought to an unselected state, the TFT1 becomes OFF and the TFT2 is electrically separated from the data line DATA, but the gate potential of the TFT2 is stably held by the holding capacitor C. The current flowing through the light emitting element OLED via the TFT2 becomes a value in accordance with a gate/source voltage Vgs, and the light emitting element OLED continuously emits the light with a brightness in accordance with the amount of the current supplied through the TFT2.

[0005]

When the current flowing between the drain and source of the TFT2 is Ids, this is the drive current flowing through the OLED. Assuming that the TFT2 operates in the saturated region, Ids is represented by the following equation.

$$Ids = \mu \cdot Cox \cdot W/L/2(Vgs-Vth)^2$$

$$= \mu \cdot Cox \cdot W/L/2(Vw - Vth)^2 2 \qquad (1)$$

Here, Cox is the gate capacity per unit area and is given by the following equation:

$$Cox = \varepsilon 0 \cdot \varepsilon r/d \qquad (2)$$

In equation (1) and equation (2), Vth indicates a threshold value of the TFT2, μ indicates a mobility of a carrier, W indicates a channel width, L indicates a channel length, $\varepsilon 0$ indicates a permittivity of vacuum, εr indicates a dielectric constant of the gate insulating film, and d is a thickness of the gate insulating film.

[0006]

According to equation (1), Ids can be controlled by the potential Vw written into the pixel. As a result, the brightness of the light emitting element OLED can be controlled. Here, the reason for the operation of the TFT2 in the saturated region is as follows. Namely, this is because, in the saturated region, Ids is controlled by only the Vgs and does not depend upon the drain/source voltage Vds. Therefore, even if Vds fluctuates due to variations in the characteristics of the OLED, a predetermined amount of the drive current Ids can be passed through the OLED.

[0007]

As mentioned above, in the circuit configuration of the pixel shown in Fig. 1, when written by Vw once, the OLED continues emitting light with a constant brightness during one scanning cycle (one frame) until next rewritten. If large number of such pixels are arranged in a matrix as in Fig. 2, an active matrix type display

device can be configured. As shown in Fig. 2, in a conventional display device, scanning lines SCAN-1 through SCAN-N for selecting pixels 25 in a predetermined scanning cycle (for example a frame cycle according to an NTSC standard) and data lines DATA giving brightness information (data potential Vw) for driving the pixels 25 are arranged in a matrix. The scanning lines SCAN-1 through SCAN-N are connected to a scanning line drive circuit 21, while the data lines DATA are connected to a data line drive circuit 22. By repeating the writing of Vw from the data lines DATA by the data line drive circuit 22 while successively selecting the scanning lines SCAN-1 through SCAN-N by the scanning line drive circuit 21, an intended image can be displayed. In a simple matrix type display device, the light emitting element contained in each pixel emits light only at an instant of selection. In contrast, in the active matrix type display device shown in Fig. 2, the light emitting element of each pixel 25 continues to emit light even after finishing being written. Therefore, in particular in a large sized, high definition display, there is the advantage that the level of the drive current of the light emitting elements can be lowered in comparison with the simple matrix type.

[0008]

Figure 3 schematically shows a sectional structure of the pixel 25 shown in Fig. 2. Note, only OLED and TFT2 are represented for facilitating the illustration. The OLED is configured by successively superposing a transparent electrode 10, an organic EL layer 11, and a metal electrode 12. The transparent electrode 10 is separated for every pixel, acts as the anode of the OLED, and is made of a transparent conductive film for example ITO. The metal electrode 12 is commonly connected among pixels and acts as the cathode of the OLED. Namely, the metal electrode 12 is commonly connected to a predetermined power supply potential Vdd. The organic EL layer 11 is a composite film obtained by superposing for example a positive hole transport layer and an electron transport layer. For example, Diamyne is vapor deposited on the transparent electrode 10 acting as the anode (positive hole injection electrode) as the positive hole transport layer, Alq3 is vapor deposited thereon as the electron transport layer. Further, a metal electrode 12 acting as the cathode (electron injection electrode) is grown thereon. Note that, Alq3 represents 8-hydroxy quinoline aluminum. The OLED having such a laminate structure is only one example. When a voltage in a forward direction (about 10V) is applied between the anode and the cathode of the OLED having such a

configuration, injection of carriers such as electrons and positive holes occurs and luminescence is observed. The operation of the OLED can be considered to be the emission of light by excitons formed by the positive holes injected from the positive hole transport layer and the electrons injected from the electron transport layer.

[0009]

On the other hand, the TFT2 comprises a gate electrode 2 formed on a substrate 1 made of glass or the like, a gate insulating film 3 superimposed on the top surface thereof, and a semiconductor thin film 4 superimposed above the gate electrode 2 via this gate insulating film 3. This semiconductor thin film 4 is made of for example a polycrystalline silicon thin film. The TFT2 is provided with a source S, a channel Ch, and a drain D acting as a passage of the current supplied to the OLED. The channel Ch is located immediately directly above the gate electrode 2. The TFT2 of this bottom gate structure is coated by an inter-layer insulating film 5. A source electrode 6 and a drain electrode 7 are formed above that. Above them, the OLED mentioned above is grown via another inter-layer insulating film 9. Note that, in the example of Fig. 3, the anode of the OLED is connected to the drain of the TFT2, so a P-channel thin film transistor is used as the TFT2.

[0010]

[Problem to be Solved by the Invention]

In an active matrix type organic EL display, generally a TFT (thin film transistor) formed on a glass substrate is utilized as the active element. This is for the following reason. Namely, an organic EL display is a direct viewing type. Due to this, it becomes relatively large in size. Due to restrictions of cost and manufacturing facilities, a usage of a single crystalline silicon substrate for the formation of the active elements is not practical. Further, in order to extract the light from the light emitting elements, usually a transparent conductive film of ITO (indium tin oxide) is used as the anode of the organic EL layer, but ITO is frequently generally grown under a high temperature which an organic EL layer cannot endure. In this case, it is necessary to form the ITO before the formation of the organic EL layer. Accordingly, the manufacture process roughly becomes as follows:

[0011]

Referring to Fig. 3 again, first the gate electrode 2, gate insulating film 3, and semiconductor thin film 4 comprised of amorphous silicon are successively stacked and patterned on the glass substrate 1 to form the TFT2. In certain cases, the amorphous silicon is sometimes

formed into polysilicon (polycrystalline silicon) by heat treatment such as laser annealing. In this case, generally a TFT2 having a larger degree of carrier mobility in comparison with amorphous silicon and a larger current driving capability can be formed. Next, an ITO transparent electrode 10 acting as the anode of the light emitting element OLED is formed. Subsequently, an organic EL layer 11 is stacked to form the light emitting element OLED. Finally, the metal electrode 12 acting as the cathode of the light emitting element is formed by a metal material (for example aluminum).

[0012]

In this case, the extraction of the light is started from a back side (bottom surface side) of the substrate 1, so a transparent material (usually a glass) must be used for the substrate 1. In view of this, in an active matrix type organic EL display, a relatively large sized glass substrate 1 is used. As the active element, ordinarily use is made of a TFT as it can be relatively easily formed thereon. Recently, attempts have also been made to extract the light from a front side (top surface side) of the substrate 1. In this case, the substrate 1 does not have to be transparent like glass, but as the transistor formed on a large sized substrate, use is generally still made of a TFT. However, the amorphous

silicon and polysilicon used for the formation of the TFT have a worse crystallinity in comparison with single crystalline silicon and have a poor controllability of the conduction mechanism, therefore it has been known that there is a large variation in characteristics in formed TFTs. Particularly, when a polysilicon TFT is formed on a relatively large sized glass substrate, usually the laser annealing method is used as mentioned above in order to avoid the problem of thermal deformation of the glass substrate, but it is difficult to uniformly irradiate laser energy to a large glass substrate. Occurrence of variations in the state of the crystallization of the polysilicon according to the location in the substrate cannot be avoided.

[0013]

As a result, it is not rare for the Vth (threshold value) to vary according to pixel by several hundreds of mV, in certain cases, 1V or more, even in the TFTs formed on an identical substrate. In this case, even if a same signal potential Vw is written with respect to for example different pixels, the Vth will vary according to the pixels. As a result, according to equation (1) described above, the current Ids flowing through the OLEDs will largely vary for every pixel and consequently become completely off from the intended value, so a high

quality of image cannot be expected as the display. A similar thing can be said for not only the Vth, but also the variation of parameters of equation (1) such as the carrier mobility μ. Further, a certain degree of fluctuation in the above parameters is unavoidable not only due to the variation among pixels as mentioned above, but also variations for every manufacturing lot or every product. In such a case, it is necessary to determine how the data line potential Vw should be set with respect to the intended current Ids to be passed through the OLEDs for every product in accordance with the final state of the parameters of equation (1). Not only is this impractical in the mass production process of displays, but it is also extremely difficult to devise countermeasures for fluctuations in characteristics of the TFTs due to the ambient temperature and changes of the TFT characteristics occurring due to usage over a long period of time. The present invention relates to a pixel circuit designed in consideration with the above problem and a drive method for the same. Its object is to provide a display device capable of stably and accurately supplying an intended current to a light emitting element etc. of a pixel without being affected by variations in characteristics of an active element inside the pixel and as a result capable of displaying a high quality image.

[0014]

[Means for Solving the Problem]

In order to achieve the object, the following means were devised. Namely, a display device according to the present invention provides a scanning line drive circuit for successively selecting scanning lines, a data line drive circuit including a current source for generating a signal current having a current level in accordance with brightness information and successively supplying the same to data lines, and a plurality of pixels arranged at intersecting portions of the scanning lines and the data lines and including current driven type light emitting elements emitting light by receiving the supply of the drive current. The characterizing feature is that each pixel comprises a receiving part for fetching the signal current from a related data line when the related scanning line is selected, a converting part for converting a current level of the fetched signal current to a voltage level and holding the same, and a drive part for passing a drive current having a current level in accordance with the held voltage level through the related light emitting element. Specifically, the converting part includes a conversion use insulating gate type field effect transistor provided with a gate, a source, a drain, and a channel and a capacitoir connected

to the gate. The conversion use insulating gate type field effect transistor generates a converted voltage level at the gate by passing the signal current fetched by the receiving part through the channel. The capacitor holds the voltage level created at the gate. Further, the converting part includes a switch use insulating gate type field effect transistor inserted between the drain and the gate of the conversion use insulating gate type field effect transistor. The switch use insulating gate type field effect transistor becomes conductive when converting the current level of the signal current to the voltage level and electrically connects the drain and the gate of the conversion use insulating gate type field effect transistor to create the voltage level with the source as the reference at the gate, while the switch use insulating gate type field effect transistor is shut off when the capacitor holds the voltage level and separates the gate of the conversion use insulating gate type field effect transistor and the capacitor connected to this from the drain.

[0015]

In one embodiment, the drive part includes a drive use insulating gate type field effect transistor provided with a gate, a drain, a source, and a channel. This drive use insulating gate type field effect transistor receives

the voltage level held at the capacitor at its gate and passes a drive current having a current level in accordance with that through the light emitting element via the channel. A current mirror circuit is configured by direct connection of the gate of the conversion use insulating gate type field effect transistor and the gate of the drive use insulating gate type field effect transistor, whereby a proportional relationship is exhibited between the current level of the signal current and the current level of the drive current. The drive use insulating gate type field effect transistor is formed in the vicinity of the corresponding conversion use insulating gate type field effect transistor inside the pixel and has an equivalent threshold voltage to that of the conversion use insulating gate type field effect transistor. The drive use insulating gate type field effect transistor operates in the saturated region and passes a drive current in accordance with a difference between the level of the voltage applied to the gate thereof and the threshold voltage through the light emitting element.

[0016]

In another embodiment, the drive part shares the conversion use insulating gate type field effect transistor together with the converting part in a time

division manner. The drive part separates the conversion use insulating gate type field effect transistor from the receiving part and uses the same for driving after the conversion of the signal current is completed and passes the drive current to the light emitting element through the channel in a state where the held voltage level is applied to the gate of the conversion use insulating gate type field effect transistor. The drive part has a controlling means for shutting off an unnecessary current flowing to the light emitting element via the conversion use insulating gate type field effect transistor at times other than the time of drive. Alternatively, the controlling means comprises a control use insulating gate type field effect transistor inserted between the conversion use insulating gate type field effect transistor and the light emitting element, and the control use insulating gate type field effect transistor becomes nonconductive in state and separates the conversion use insulating gate type field effect transistor and the light emitting element when the light emitting element is not driven and switches to the conductive state when the light emitting element is driven. In addition, the controlling means controls a ratio between a time for cutting off the drive current when the light emitting element is not to be driven and

placing the light emitting element in the non-light emitting state and a time of passing the drive current when the light emitting element is to be driven and placing the light emitting element in the light emitting and thereby to enable the control of the brightness of the pixel. According to a certain case, the drive part has a potential fixing means for fixing the potential of the drain with reference to the source of the conversion use insulating gate type field effect transistor in order to stabilize the current level of the drive current flowing to the light emitting element through the conversion use insulating gate type field effect transistor.

[0017]

In a further developed form of the present invention, the receiving part, the converting part, and the drive part configure a current circuit combining a plurality of insulating gate type field effect transistors, and one or two or more insulating gate type field effect transistors have a double gate structure for suppressing current leakage in the current circuit. Further, the drive part includes the insulating gate type field effect transistor provided with the gate, drain, and the source and passes the drive current passing between the drain and the source to the light emitting

element in accordance with the level of the voltage applied to the gate, the light emitting element is a two terminal type having an anode and a cathode, and the cathode is connected to the drain. Alternatively, the drive part includes an insulating gate type field effect transistor provided with a gate, a drain, and a source and passes a drive current passing between the drain and the source to the light emitting element in accordance with the level of the voltage applied to the gate, the light emitting element is a two terminal type having an anode and a cathode, and the anode is connected to the source. Further, it includes an adjusting means for downwardly adjusting the voltage level held by the converting part and supplying the same to the drive part to tightens the black level of the brightness of each pixel. In this case, the drive part includes an insulating gate type field effect transistor having a gate, a drain, and a source, and the adjusting means downwardly adjusts the level of the voltage applied to the gate by raising the bottom of the voltage between the gate and the source of the insulating gate type field effect transistor. Alternatively, the drive part includes an insulating gate type field effect transistor having a gate, a drain, and a source, the converting part is provided with a capacitor connected to the gate of the

thin film transistor and holding the voltage level, and the adjusting means comprises an additional capacitor connected to that capacitor and downwardly adjusts the level of the voltage to be applied to the gate of the insulating gate type field effect transistor held at that capacitor. Alternatively, the drive part includes an insulating gate type field effect transistor having a gate, a drain, and a source, the converting part is provided with a capacitor connected to the gate of the insulating gate type field effect transistor on its one end and holding the voltage level, and the adjusting means adjusts the potential of the other end of the capacitor when holding the voltage level converted by the converting part at that capacitor to downwardly adjust the level of the voltage to be applied to the gate of the insulating gate type field effect transistor. Note that, as the light emitting element, use is made of for example an organic electroluminescence element.

[0018]

The pixel circuit of the present invention has the following characteristic features. First, the brightness information is written to a pixel by passing a signal current having a magnitude in accordance with the brightness through the data line. That current flows between the source and the drain of the conversion use

insulating gate type field effect transistor inside the pixel and as a result creates a voltage between the gate and source in accordance with the current level. Second, the voltage between the gate and source created as described above or the gate potential is held by the function of the capacitor formed inside the pixel or existing parasitically and is held at about that level for a predetermined period even after the end of the writing. Third, the current flowing through the OLED is controlled by the conversion use insulating gate type field effect transistor per se connected to it in series or the drive use insulating gate type field effect transistor provided inside the pixel separately from that and having a gate commonly connected together with the conversion use insulating gate type field effect transistor. The voltage between the gate and source at the OLED drive is generally equal to the voltage between the gate and source of the conversion use insulating gate type field effect transistor created according to the first characterizing feature. Fourth, at the time of writing, the data line and the internal portion of the pixel are made conductive by a fetching use insulating gate type field effect transistor controlled by the first scanning line, and the gate and the drain of the conversion use insulating gate type field effect

transistor are short-circuited by the switch use insulating gate type field effect transistor controlled by the second scanning line. Summarizing the above, while in the conventional example, the brightness information was given in the form of a voltage value, in contrast, the remarkable characterizing feature of the display device of the present invention is that the brightness information is given in the form of a current value, that is, of a current written type.

[0019]

As already mentioned, an object of the present invention is to accurately pass the intended current through the OLEDs without being affected by variations in the characteristics of the TFTs. The reason why the present object can be achieved by the first through fourth characterizing features will be explained below. Note that hereinafter the conversion use insulating gate type field effect transistor will be described as the TFT1, the drive use insulating gate type field effect transistor will be described as the TFT2, the fetching use insulating gate type field effect transistor will be described as the TFT3, and the switch use insulating gate type field effect transistor will be described as the TFT4. Note that the present invention is not limited to TFTs (thin film transistors). Insulating gate type field

effect transistors can be widely employed as the active elements, for example, single crystalline silicon transistors formed on a single crystalline silicon substrate or SOI substrate. The signal current passing through the TFT1 at the time of writing of the brightness information is defined as Iw, and the voltage between the gate and source created in the TFT1 as a result of this is defined as Vgs. At the time writing, due to the TFT4, the gate and the drain of the TFT1 are short-circuited, so the TFT1 operates in the saturated region. Accordingly, Iw is given by the following equation.

$$Iw = \mu 1 \cdot Cox1 \cdot W1/L1/2(Vgs-Vth1)^2 \quad (3)$$

Here, the meanings of the parameters are similar to the case of equation (1). Next, when defining the current flowing through an OLED as Idrv, Idrv is controlled in its current level by the TFT2 connected to the OLED in series. In the present invention, the voltage between the gate and source thereof coincides with Vgs in equation (3). Therefore, when assuming that the TFT2 operates in the saturated region, the following equation stands:

$$Idrv = \mu 2 \cdot Cox\ 2 \cdot W2/L2/2(Vgs-Vth2)^2 \quad (4)$$

The meanings of the parameters are similar to the case of equation (1). Note that, the condition for the operation of the insulating gate type field effect transistor in the saturated region is generally given by

the following equation while defining Vds as the voltage between the drain and source.

$$|Vds| > |Vgs-Vth| \qquad (5)$$

[0020]

Here, TFT1 and TFT2 are formed close inside a small pixel, so it can be considered that de facto $\mu1 = \mu2$, Cox1 = Cox2, and Vth1 = Vth2. Then, at this time, the following equation is easily derived from equation (3) and equation (4):

$$Idrv/Iw = (W2/L2)/(W1/L1) \qquad (6)$$

The point to be noted here resides in the fact that, in equation (3) and equation (4), the values of μ, Cox, and Vth per se vary for every pixel, every product, or every manufacturing lot, but equation (6) does not include these parameters, so the value of Idrv/Iw is not affected by such variation of them. For example, when designing W1 = W2 and L1 = L2, Idrv/Iw = 1 stands, that is, Iw and Idrv become an identical value. Namely, the drive current Idrv flowing through the OLED becomes accurately identical to the signal current Iw without being affected by variations in the characteristics of the TFT. Therefore, as a result, the light emitting brightness of the OLED can be accurately controlled. The above description is just one example. As will be explained below by giving embodiments, the ratio of Iw

and Idrv can be freely determined according to how W1, W2, L1, and L2 are set. Alternatively, it is also possible to use the same TFT for the TFT1 and TFT2.

[0021]

In this way, according to the present invention, the correct current can be passed through the OLED without being affected by variations in the characteristics of the TFT. Further, according to equation (6), there is the large advantage of the simple proportional relationship between Iw and Idrv. Namely, in the conventional example of Fig. 1, as shown in equation (1), Vw and Idrv are nonlinear and are affected by variations in the characteristics of the TFT, so the control of the voltage at the drive side becomes complex. Further, it is seen that the carrier mobility μ among the characteristics of the TFT shown in equation (1) fluctuates according to the temperature. In this case, in the conventional example, according to equation (1), Idrv, and accordingly the light emitting brightness of the OLED, changes, but according to the present invention, such a worry does not exist. The value of Idrv given by equation (6) can be stably supplied to the OLED.

[0022]

In equation (4), it was assumed that the TFT2 operated in the saturated region, but the present

invention is effective in also a case where the TFT2 operates in a linear region. Namely, where the TFT2 operates in the linear region, Idrw is given by the following equation:

$$Idrv = \mu 2 \cdot Cox2 \cdot W2/L2 * \{(Vgs-Vth2)Vds2 - Vds2^2/2\} \qquad (7)$$

Vds2 is the voltage between the drain and source of TFT2. Here, when assuming that TFT1 and TFT2 are arranged close and as a result Vth1 = Vth2 = Vth stands, Vgs and Vth can be deleted from equation (3) and equation (7) and the following equation is obtained:

$$Idrv = \mu 2 \cdot Cox2 \cdot W2/L2 * \{(2Iw \cdot L1/\mu 1 \cdot Cox1 \cdot W1)^{1/2} Vds2 - Vds2^2/2\} \qquad (8)$$

In this case, the relationship between Iw and Idrv does not become a simple proportional relationship as in equation (6), but Vth is not contained in equation (8). Therefore, it is seen that the relationship of Iw and Idrv is not affected by the variation of Vth (variation in a screen or variation for every manufacturing lot). Namely, by writing the predetermined Iw without being affected by variation of the Vth, the intended Idrv can be obtained. Note, where μ and Cox vary in the screen, due to these values, even if a specific Iw is given to the data line, the value of Idrv determined from equation (8) will vary. Therefore desirably the TFT2 operates in

the saturated region as mentioned before.

[0023]

[Embodiments of Invention]

Figure 4 shows an example of a pixel circuit according to the present invention. This circuit comprises, other than the conversion use transistor TFT1 with the signal current flowing therethrough and the drive use transistor TFT2 for controlling the drive current flowing through a light emitting element made of an organic EL element or the like, a fetch use transistor TFT3 for connecting or disconnecting the pixel circuit and the data line DATA by the control of a first scanning line SCAN-A, a switch use transistor TFT4 for short-circuiting the gate and the drain of the TFT1 during the writing period by the control of a second scanning line SCAN-B, a capacitor C for holding the voltage between the gate and source of the TFT1 even after the end of the writing, and the light emitting element OLED. In Fig. 4, TFT3 is configured by a PMOS, and the other transistors are configured by NMOSs, but this is one example. The invention does not always have to be this way. The capacitor C is connected to the gate of the TFT1 at its one terminal, and connected to the GND (ground potential) at its other terminal, but this is not limited to GND. Any constant potential is possible. The anode of the OLED

is connected to the positive power supply potential Vdd.

[0024]

Basically, the display device according to the present invention is provided with a scanning line drive circuit for successively selecting scanning lines SCAN-A and SCAN-B, a data line drive circuit including a current source CS for generating a signal current Iw having a current level in accordance with the brightness information and successively supplying the same to the data lines DATA, and a plurality of pixels arranged at intersecting portions of the scanning lines SCAN-A and SCAN-B and data lines DATA and including current drive type light emitting elements OLED emitting light by receiving the supply of the drive current. As the characterizing feature, each pixel shown in Fig. 4 comprises a receiving part for fetching the signal current Iw from the related data line DATA when the related scanning line SCAN-A is selected, a converting part for once converting the current level of the fetched signal current Iw to the voltage level and holding the same, and a drive part for passing the drive current having the current level in accordance with the held voltage level through the related light emitting element OLED. Specifically, the converting part includes a conversion use thin film transistor TFT1 provided with a

gate, source, drain, and channel and the capacitor C connected to the gate. The conversion use thin film transistor TFT1 generates a converted voltage level at the gate by passing the signal current Iw fetched by the receiving part through the channel, while the capacitor C holds the voltage level created at the gate. Further, the converting part includes the switch use thin film transistor TFT4 inserted between the drain and gate of the conversion use thin film transistor TFT1. The switch use thin film transistor TFT4 becomes conductive when converting the current level of the signal current Iw to the voltage level, electrically connects the drain and gate of the conversion use thin film transistor TFT1, and creates the voltage level with reference to the source at the gate of the TFT1. Further, the switch use thin film transistor TFT4 is cut off when the capacitor C holds the voltage level and separates the gate of the conversion use thin film transistor TFT1 and the capacitor C connected to this from the drain of the TFT1.

[0025]

Further, the drive part includes a drive use thin film transistor TFT2 provided with a gate, drain, source, and channel. The drive use thin film transistor TFT2 receives the voltage level held at the capacitor C at its gate and passes a drive current having a current level in

accordance with that via the channel to the light emitting element OLED. A current mirror circuit is configured by direct connection of the gate of the conversion use thin film transistor TFT1 and the gate of the drive use thin film transistor TFT2, whereby a proportional relationship is exhibited between the current level of the signal current Iw and the current level of the drive current. The drive use thin film transistor TFT2 is formed in the vicinity of the corresponding conversion use thin film transistor TFT1 inside the pixel and has an equivalent threshold voltage to that of the conversion use thin film transistor TFT1. The drive use thin film transistor TFT2 operates in the saturated region and passes a drive current in accordance with the difference between the level of the voltage applied to the gate thereof and the threshold voltage to the light emitting element OLED.

[0026]

The driving method of the present pixel circuit is as follows. The drive waveforms are shown in Fig. 5. First, at the time of writing, the first scanning line SCAN-A and the second scanning line SCAN-B are brought into the selected state. In the example of Fig. 5, SCAN-A is set at a low level, and SCAN-B is set at a high level. By connecting the current source CS to the data line DATA

in a state where both scanning lines are selected, the signal current Iw in accordance with the brightness information flows through the TFT1. The current source CS is a variable current source controlled in accordance with the brightness information. At this time, the gate and the drain of the TFT1 are short-circuited by the TFT4, and therefore equation (5) stands, and the TFT1 operates in the saturated region. Accordingly, between the gate and the source thereof, a voltage Vgs given by equation (3) is created. Next, SCAN-A and SCAN-B are brought to the unselected state. In more detail, first SCAN-B is set at a low level and the TFT4 is brought into an off state. By this, Vgs is held by the capacity C. Next, by setting SCAN-A at a high level and bringing it to the off state, the pixel circuit and the data line DATA are electrically cut off, and therefore, the writing to the other pixel can be carried out via the data line DATA thereafter. Here, the data output by the current source CS as the current level of the signal current must be effective at the point of time when SCAN-B becomes unselected, but after that, may be set at any level (for example the write data of the next pixel). The gate and the source of the TFT2 are commonly connected together with the TFT1. Further, the two are formed close inside a small pixel. Therefore, if the TFT2 operates in the

saturated region, the current flowing through the TFT2 is given by equation (4). This becomes the drive current Idrv flowing through OLED. In order to operate the TFT2 in the saturated region, a sufficient positive potential may be given to the Vdd so that equation (5) still stands even if a voltage drop at OLED is considered.

[0027]

According to the above drive, the current Idrv flowing through the light emitting element OLED is given by the previous equation (6):

$$Idrv = (W2/L2)/(W1/L1) \cdot Iw$$

and a value correctly proportional to Iw without being affected by variations in the characteristics of the TFT is obtained. The proportional constant (W2/L2)/(W1/L1) can be set to a proper value by considering various circumstances. For example, where assuming that the value of the current to be passed through the OLED of one pixel is a relatively small value, for example 10 nA, as the actual problem, it is sometimes difficult to correctly supply such a small current value as the signal current Iw. In such a case, if a design is made so that (W2/L2)/(W1/L1) = 1/100 stands, Iw becomes 1 μA from equation (6) and the current write operation becomes easy.

[0028]

In the above example, it was assumed that the TFT2

operated in the saturated region, but the present invention is effective even in the case where the TFT2 operates in the linear region as mentioned before. Namely, where the TFT2 operates in the linear region, the current Idrv flowing through OLED is given by the above equation (8):

$$Idrv = \mu 2 \cdot Cox2 \cdot W2/L2 * \{(2Iw \cdot L1/\mu 1 \cdot Cox1 \cdot W1)^{1/2} Vds2 - Vds2^2/2\}$$

In the above equation, Vds2 is determined by current-voltage characteristics of OLED and the current Idrv flowing through OLED. When the potential of Vdd and the characteristics of OLED are given, it is a function of only Idrv. In this case, the relationship between Iw and Idrv does not become the simple proportional relationship as in equation (6), but if Iw is given, the Idrv satisfying equation (8) becomes the drive current flowing through OLED. Vth is not contained in equation (8), therefore it is seen that the relationship between Iw and Idrv is not affected by the variation of Vth (variation for every pixel in the screen or variation for every manufacturing lot). Namely, by writing the intended Iw without being affected by variation in the Vth, the intended Idrv can be obtained.

[0029]

Figure 6 shows an example of the display device

configured by arranging the pixel circuits of Fig. 4 in the matrix state. The operation thereof will be explained below. First, a vertical start pulse (VSP) is input to a scanning line drive circuit A21 including the shift register and a scanning line drive circuit B23 similarly including the shift register. After receiving VSP, the scanning line drive circuit A21 and scanning line drive circuit B23 successively select first scanning lines SCAN-A1 to SCAN-AN and second scanning lines SCAN-B1 to SCAN-BN synchronous to the vertical clocks (VCKA, VCKB). The current source CS is provided in the data line drive circuit 22 corresponding to each data line DATA and drives the data line at a current level in accordance with the brightness information. The current source CS comprises an illustrated voltage/current conversion circuit and outputs the signal current in accordance with the voltage representing the brightness information. The signal current flows through the pixel on the selected scanning line, and the current is written in units of the scanning lines. Each pixel starts to emit light with an intensity in accordance with its current level. Note, VCKA is slightly delayed relative to VCKB by a delay circuit 24. By this, as shown in Fig. 5, SCAN-B becomes unselected preceding SCAN-A.

[0030]

Figure 7 is a modification of the pixel circuit of Fig. 4. This circuit gives a double gate configuration wherein two transistors TFT2a and TFT2b are connected in series to the TFT2 in Fig. 4 and imparts a double gate configuration wherein two transistors TFT4a and TFT4b are connected in series to the TFT4 in Fig. 4. The gates of the TFT2a and TFT2b and the gates of the TFT4a and TFT4b are commonly connected, therefore basically they perform a similar operation to that of single transistors. As a result, also the pixel circuit of Fig. 7 performs a similar operation to that of the pixel circuit of Fig. 4. With a single transistor, particularly TFT, there is a case where the leakage current at the off time becomes large according to a certain defect or the like. For this reason, when it is intended to suppress the leakage current, preferably a redundant configuration of connecting a plurality of transistors in series is employed. This is because, when employing this, even if there is a leakage in one transistor, if the leakage of the other transistor is small, the leakage as a whole can be suppressed. When employing the configuration such as TFT2a and TFT2b of Fig. 7, due to the small leakage current, there arises a merit that the quality of the black level of the display becomes good when the brightness is zero (current zero). Further, when

employing the configuration such as TFT4a and TFT4b, there arises a merit that the brightness information written in the capacitor C can be stably held. For these, similarly, it is also possible to configure three or more transistors in series. As described above, in the present modification, the receiving part, converting part, and the drive part configure the current circuit combining a plurality of thin film transistors TFT. One or more thin film transistors (TFT) have the double gate structure for suppressing the current leakage in the current circuit.

[0031]

Figure 8 shows another embodiment of the pixel circuit according to the present invention. The characterizing feature of this circuit resides in that the transistor TFT1 with the signal current Iw flowing therethrough per se controls the current Idrv flowing through OLED. In the pixel circuit shown in Fig. 4 mentioned before, when the characteristics of TFT1 and TFT2 (Vth, μ or the like) are slightly different from each other, equation (6) does not correctly stand, and there is a possibility such that Iw and Idrv are not correctly proportional, but in the pixel circuit of Fig. 8, such a problem does not occur in principle. The pixel circuit of Fig. 8 is provided with, other than the TFT1, a transistor TFT3 for connecting or disconnecting the

pixel circuit and the data line DATA under the control of the first scanning line SCAN-A, a transistor TFT4 for short-circuiting the gate and the drain of the TFT1 during the writing period by the control of the second scanning line SCAN-B, a capacitor C for holding the voltage between the gate and source of the TFT1 even after the end of the writing, and a light emitting element OLED made of the organic EL element. The holding capacitor C is connected to the gate of the TFT1 at its one terminal and connected to the GND (ground potential) at its other terminal, but this is not limited to GND. Any constant potential is possible. The anode of OLED is connected to the anode line A arranged in units of the scanning lines. The TFT3 is configured by a PMOS, and the other transistors are configured by NMOSs, but this is one example. The invention does not always have to be this way.

[0032]

As described above, in the present embodiment, the drive part of the pixel circuit shares the conversion use thin film transistor TFT1 in a time division manner together with the conversion unit. Namely, the drive part separates the conversion use thin film transistor TFT1 from the receiving part after completing the conversion of the signal current Iw and uses the same for drive and

passes the drive current to the light emitting element OLED through the channel in the state where the held voltage level is applied to the gate of the conversion use thin film transistor TFT1. Further, the drive part has a controlling means for cutting off the unnecessary current flowing through the light emitting element OLED via the conversion use thin film transistor TFT1 at times other than the drive. In the case of the present example, the controlling means controls the voltage between terminals of the two terminal type light emitting elements OLED having the rectification function by the anode line A and cuts off the unnecessary current.

[0033]

The driving method of this circuit is as follows. The drive waveform is shown in Fig. 9. First, the first scanning line SCAN-A and the second scanning line SCAN-B are brought to the selected state at the time of writing. In the example of Fig. 9, SCAN-A is set at a low level, and SCAN-B is set at a high level. Here, the current source CS of the current value Iw is connected to the data line DATA, but in order to prevent the Iw from flowing via OLED, the anode line A of OLED is set at low level (for example GND or negative potential) so that OLED becomes the off state. By this, the signal current Iw flows through the TFT1. At this time, the gate and the

drain of the TFT1 are electrically short-circuited by the TFT4, therefore equation (5) stands, and the TFT1 operates in the saturated region. Accordingly, the voltage Vgs given by equation (3) is created between the gate and the source thereof. Next, SCAN-A and SCAN-B are brought to the unselected state. In more detail, first, SCAN-B is brought to the low level and the TFT4 is brought to the off state. By this, the Vgs created in the TFT1 is held at the capacity C. Next, by setting the SCAN-A at the high level and bringing the TFT3 to the off state, the pixel circuit and the data line DATA are electrically cut off, and therefore the writing to another pixel can be carried out via the data line DATA after that. Here, the data supplied by the current source CS as the signal current Iw must be valid at a point of time when SCAN-B becomes unselected, but may be set at any value (for example write data of the next pixel) after that. Then, the anode line A is brought to the high level. The Vgs of the TFT1 is held by the capacitor C, therefore if the TFT1 operates in the saturated region, the current flowing through the TFT1 coincides with Iw in equation (3). This becomes the drive current Idrv flowing through the light emitting element OLED. That is, the signal current Iw coincides with the drive current Idrv of OLED. In order to operate the TFT1 in the saturated

region, a sufficient positive potential may be given to the anode line A so that equation (5) still stands even if the voltage drop at OLED is considered. According to the above drive, the current Idrv flowing through OLED correctly coincides with Iw without being affected by variations in the characteristics of the TFT.

[0034]

Figure 10 is a modification of the pixel circuit shown in Fig. 8. In Fig. 10, there is no anode line as in Fig. 8. The anode of OLED is connected to the constant positive potential Vdd, while a P-channel transistor TFT5 is inserted between the drain of the TFT1 and the cathode of the OLED. The gate of the TFT5 is controlled by the drive line drv arranged in units of the scanning lines. The object of insertion of TFT5 is prevention of the flow of the signal current Iw via the OLED by setting the drive line drv at a high level and bringing the TFT5 to the off state at the time of writing data. After the writing is ended, the drv is brought to the low level, the TFT5 is brought to the on state, and the drive current Idrv flows through the OLED. The rest of the operation is similar to that of the circuit of Fig. 8.

[0035]

The present example includes the TFT5 connected to the light emitting element OLED in series and can cut off

the current flowing to the light emitting element OLED in accordance with the control signal given to the TFT5. The control signal is given to the gate of the TFT5 included in each pixel on the identical scanning line via the drive line drv provided in parallel to the scanning line SCAN. In the present example, the TFT5 is inserted between OLED and the TFT1, and the current flowing through OLED can be turned on or off by the control of the gate potential of the TFT5. According to the present example, the emission of light of each pixel is achieved for the amount of time where the TFT5 is on by a light emission control signal. When defining the on time as τ and the time of one frame as T, the ratio in time when the pixel is emitting light, that is, the duty, becomes approximately τ/T. A time average brightness of the light emitting element changes in proportional to this duty. Accordingly, by changing the on time τ by controlling the TFT5, it is also possible to variably adjust the screen brightness of the EL display conveniently and in a wide range.

[0036]

As described above, in the present example, the controlling means comprises the control use thin film transistor TFT5 inserted between the conversion use thin film transistor TFT1 and the light emitting element OLED.

The control use thin film transistor TFT5 becomes nonconductive and separates the conversion use thin film transistor TFT1 and the light emitting element OLED when OLED is not driven and switches to the conductive state at the time of drive. Further, this controlling means can control the brightness of each pixel by controlling the ratio between the off time for which the drive current is cut off and the light emitting element OLED is placed in the non-light emitting state when the OLED is not to be driven and the on time for which the drive current is passed and the light emitting element OLED is placed in the light emitting state when the OLED is to be driven. According to the present example, before the brightness information of the next scanning line cycle (frame) is newly written after writing the brightness information into the pixels in units of the scanning lines, the display device can extinguish the light emitting elements contained in the pixels in units of the scanning lines together. This means that the time from the lighting to the extinguishing of the light emitting elements after the writing of the brightness information can be adjusted. Namely, it means that the ratio (duty) of the light emitting time in one scanning line cycle can be adjusted. The adjustment of the light emitting time (duty) corresponds to the adjustment of the drive current

supplied to each light emitting element. Accordingly, it is possible to adjust the display brightness conveniently and freely by adjusting the duty. A further important point resides in that the drive current can be equivalently made large by adequately setting the duty. For example, when the duty is set at 1/10, even if the drive current is increased to 10 times, an equivalent brightness is obtained. If the drive current is made 10 times large, also the signal current corresponding to this can be made 10 times larger, and therefore it is not necessary to handle a weak current level.

[0037]

Figure 11 is another modification of the pixel circuit shown in Fig. 8. In Fig. 11, a TFT6 is inserted between the drain of the TFT1 and the cathode of OLED, a TFT7 is connected between the gate and the drain of the TFT6, and the gate thereof is controlled by the second scanning line SCAN-B. An auxiliary capacity C2 is connected between the source of the TFT7 and the GND potential. The driving method of this circuit is basically the same as the case of the pixel circuit of Fig. 8, but will be explained below. Note that, the drive waveform is similar to that of the case of Fig. 9. First, at the time of writing, when SCAN-A and SCAN-B are brought to the selected state in the state where the

anode line A arranged in units of the scanning lines is brought to the low level (for example GND or negative potential) and the current is prevented from flowing through OLED, the signal current Iw flows through the TFT1 and TFT6. Since the gates and the sources are short-circuited by the TFT4 and TFT7, the two TFTs operate in the saturated region. Next, SCAN-A and SCAN-B are brought to the unselected state. By this, the Vgs previously created in the TFT1 and the TFT6 are held by the capacitor C and the auxiliary capacitor C2. Next, by bringing SCAN-A to the off state, the pixel circuit and the data line DATA are electrically cut off, therefore the writing to another pixel can be carried out via the data line DATA after that. Then, the anode line A is set at a high level. Since the Vgs of the TFT1 is held by the capacitor C, if the TFT1 operates in the saturated region, the current flowing through the TFT1 coincides with Iw of equation (3). This becomes the current Idrv flowing through OLED. That is, the signal current Iw coincides with the drive current Idrv of OLED.

[0038]

Here, an explanation will be made of the function of the TFT6. In the pixel circuit of Fig. 8, as mentioned before, both of the signal current Iw and the drive current of OLED are determined by the TFT1, therefore Iw

= Idrv stood by equation (3) and equation (4). Note, this is true when assuming a case where the current Ids flowing through the TFT1 is given by equation (1) in the saturated region, that is, Ids does not depend on the voltage Vds between the drain and the source. Nevertheless, in an actual transistor, even if Vgs is constant, the larger Vds, the larger Ids in a certain case. This is due to the so-called short channel effect where a pinchoff point in the vicinity of the drain moves to the source by an increase of the Vds, and an effective channel length is reduced, or a so-called back gate effect where the potential of the drain exerts an influence upon the channel potential, and the conduction rate of the channel changes, and so on. In this case, the current Ids flowing through the transistor becomes for example as in the following equation.

$$\mathrm{Ids} = \mu \cdot \mathrm{Cox} \cdot W/L/2(\mathrm{Vgs} - \mathrm{Vth})^2 * (1+ \lambda \cdot \mathrm{Vds}) \qquad (9)$$

Accordingly, Ids will depend on Vds. Here, λ is a positive constant. In this case, in the circuit of Fig. 8, Iw does not coincide with Idrv unless Vds is not identical between the time of the writing and the time of the drive.

[0039]

As opposed to this, the operation of the circuit of

Fig. 11 will be considered. When paying attention to the operation of the TFT6 of Fig. 11, the drain potential thereof is not generally identical between the time of the writing and the time of the drive. For example, where the drain potential at the time of the drive is higher, the Vds of the TFT6 becomes larger. When inserting this in equation (9), even if Vgs is constant between the time of the writing and the time of the drive, Ids is increased at the time of the drive. In other words, Idrv becomes bigger than Iw, and the two do not coincide. However, the Idrv flows through the TFT1, therefore, in that case, the voltage drop at the TFT1 becomes large and the drain potential thereof (source potential of the TFT6) rises. As a result, Vgs of the TFT6 becomes small. This acts in a direction reducing the Idrv. As a result, the drain potential of the TFT1 (source potential of the TFT6) cannot largely fluctuate. When paying attention to the TFT1, it is seen that Ids does not largely change between the time of the writing and the time of the drive. Namely, Iw and Idrv will coincide with a remarkably high precision. In order to perform this operation better, it is good if the dependency of Ids with respect to Vds is made small in both of the TFT1 and TFT6, therefore desirably both transistors are operated in the saturated region. At the time of writing, the gate

and the drain are short-circuited in both of the TFT1 and TFT6. Therefore, regardless of the brightness data written, the two operate in the saturated region. In order to operate them also at the drive, a sufficient positive potential may be given to the anode line A so that the TFT6 still operates in the saturated region even if the voltage drop at OLED is considered. By this drive, the current Idrv flowing through OLED more correctly coincides with the Iw than the embodiment of Fig. 8 without being affected by variations in the characteristics of the TFT. As described above, the drive part of the present example has TFT6, TFT7, and C2 as potential fixing means for fixing the potential of the drain with reference to the source of the conversion use thin film transistor TFT1 for stabilizing the current level of the drive current flowing to the light emitting element OLED through the conversion use thin film transistor TFT1.

[0040]

Figure 12 is another embodiment of the pixel circuit according to the present invention. The characterizing feature of this pixel circuit resides in that, in the same way as Fig. 8, Fig. 10, and Fig. 11, the transistor TFT1 per se with the signal current Iw flowing therethrough controls the current Idrv flowing through

OLED, but in Fig. 12, OLED is connected to the source side of the TFT1. Namely, the drive part of the present pixel circuit includes the thin film transistor TFT1 provided with the gate, drain, and the source and passes the drive current passing between the drain and the source to the light emitting element OLED in accordance with the level of the voltage applied to the gate. The light emitting element OLED is a two-terminal type having an anode and a cathode, and the anode is connected to the source. On the other hand, the drive part of the pixel circuit shown in Fig. 8 includes the thin film transistor provided with the gate, drain, and the source and passes the drive current passing between the drain and the source to the light emitting element in accordance with the level of the voltage applied to the gate. The light emitting element is the two-terminal type having an anode and a cathode, and the cathode is connected to the drain.

[0041]

The pixel circuit of the present example comprises, other than the TFT1, a transistor TFT3 for connecting or shutting off the pixel circuit and the data line DATA by the control of the first scanning line SCAN-A, a transistor TFT4 for short-circuiting the gate and the drain of the TFT1 during the writing period by the control of the second scanning line SCAN-B, a capacitor C

for holding the gate potential of the TFT1 even after the end of the writing, a P-channel transistor TFT5 inserted between the drain of the TFT1 and the power supply potential Vdd, and the light emitting element OLED. In Fig. 12, one terminal of the capacitor C is connected to the GND, and the Vgs of the TFT1 is held at schematically the same value between the time of the writing and the time of the drive. Note that, the gate of the TFT5 is controlled by the drive line drv. The object of the insertion of the TFT5 is to bring the TFT5 into the off state by setting the drive line drv at the high level at the time of writing data and pass all of the signal current Iw through the TFT1. After the writing is ended, the drv is brought to the low level, the TFT5 is brought to the on state, and the drive current Idrv is passed through OLED. In this way, the driving method is similar to that of the circuit of Fig. 10.

[0042]

Figure 13 is a modification of the pixel circuit shown in Fig. 12. In Fig. 12 and Fig. 13, the difference resides in that one terminal of the capacitor C is connected to the GND in Fig. 12, but is connected to the source of the TFT1 in Fig. 13, but in both cases, there is no functional difference in the point that the Vgs of the TFT1 is held at schematically the same value between

the time of the writing and the time of the drive.

[0043]

Figure 14 is a more developed example of the pixel circuit shown in Fig. 4. The present pixel circuit includes an adjusting means for downwardly adjusting the voltage level held by the converting part and supplying the same to the drive part to tighten the black level of the brightness of each pixel. Concretely, the drive part includes a thin film transistor TFT2 having a gate, drain, and source and an adjusting means provided with a constant voltage source E for raising the bottom of the voltage between the gate and the source of the thin film transistor TFT2 and downwardly adjusting the level of the voltage applied to the gate. Namely, it tightens the black level by connecting the source of the TFT2 to the potential E slightly higher than the source potential of the TFT1.

[0044]

Figure 15 is a modification of the pixel circuit shown in Fig. 14. In the present example, the adjusting procedure is comprised by an additional capacitor C2 connected to the gate of the thin film transistor TFT2 and the scanning line SCAN-B and downwardly adjusts the voltage level to be held at the capacitor C for applying the same to the gate of the thin film transistor TFT2.

Namely, when switching SCAN-B to the low level and bringing it to the unselected state, the gate potential of the TFT2 can be slightly lowered by the function of C2. As described above, in the present display device, the scanning line SCAN-A for selecting the pixel and the data line DATA giving the brightness information for driving the pixel are arranged in the matrix state. Each pixel includes the light emitting element OLED having the brightness changing according to the amount of the supplied current, the writing means (TFT1, TFT3, C) controlled by the scanning line SCAN-A and writing the brightness information given from the data line DATA to the pixel, and the driving means (TFT2) for controlling the amount of the current supplied to the light emitting element OLED in accordance with the written brightness information. The brightness information is written into each pixel by applying the electric signal Iw in accordance with the brightness information to the data line DATA in the state where the scanning line SCAN A is selected. The brightness information written in each pixel is held at each pixel even after the scanning line SCAN-A becomes unselected. The light emitting element OLED of each pixel includes the adjusting means (C2) capable of maintaining the lighting with the brightness in accordance with the held brightness information,

downwardly adjusting the brightness information written by the writing means (TFT1, TFT3, C), and supplying the same to the drive means (TFT2) and can tighten the black level of the brightness of each pixel.

[0045]

Figure 16 is a modification of the pixel circuit shown in Fig. 14. In the present example, the adjusting procedure downwardly adjusts the level of the voltage to be applied to the gate of the TFT2 by adjusting the potential of one end of the capacitor C when holding the voltage level converted by the TFT1 at the capacitor C. Namely, by controlling the source potential control line S connected to one end of the capacitor C, the black level is tightened. This is because the gate potential of the TFT2 is slightly lowered by the function of the capacitor C when setting the potential control line S at a lower potential than that at the writing. The potential control line S is provided in units of the scanning lines and controlled. The potential control line S is brought to an "H" level during the writing and brought to an "L" level after the end of the writing. When defining an amplitude as ΔVs and defining the capacity existing at the gate of the TFT2 (gate capacity, other parasitic capacity) as Cp, the gate potential of the TFT2 is lowered by exactly $\Delta Vg = \Delta Vs*C/(C+Cp)$, and Vgs becomes

small. The absolute values of the H and L potentials can be freely set.

[0046]

[Effects of the Invention]

According to the pixel circuit and drive method of the present invention, it is possible to pass a drive current Idrv correctly proportional (or corresponding) to the signal current Iw from a data line to a current drive type light emitting element (organic EL element or the like) without being affected by variations in the characteristics of the active element (TFT etc.) By arranging a large number of pixel circuits including such current drive circuits in a matrix, each pixel can be made to correctly emit light with the intended brightness. Therefore it is possible to provide a high quality active matrix type display device.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[Fig. 1]

A circuit diagram of an example of a conventional pixel circuit.

[Fig. 2]

A block diagram of an example of the configuration of a conventional display device.

[Fig. 3]

A sectional view of an example of the configuration

of a conventional display device.

[Fig. 4]

A circuit diagram of an embodiment of a pixel circuit according to the present invention.

[Fig. 5]

A waveform diagram of an example of waveforms of signals in the embodiment of Fig. 4.

[Fig. 6]

A block diagram of an example of the configuration of a display device using a pixel circuit according to the embodiment of Fig. 4.

[Fig. 7]

A circuit diagram of a modification of the embodiment of Fig. 4.

[Fig. 8]

A circuit diagram of another embodiment of a pixel circuit according to the present invention.

[Fig. 9]

A waveform diagram of an example of the waveforms of signals in the embodiment of Fig. 8.

[Fig. 10]

A circuit diagram of a modification of the embodiment of Fig. 8.

[Fig. 11]

A circuit diagram of a modification of the

embodiment of Fig. 8.

[Fig. 12]

A circuit diagram of a modification of the embodiment of Fig. 8.

[Fig. 13]

A circuit diagram of a modification of the embodiment of Fig. 8.

[Fig. 14]

A circuit diagram of another embodiment of the pixel circuit according to the present invention.

[Fig. 15]

A circuit diagram of a modification of the embodiment of Fig. 14.

[Fig. 16]

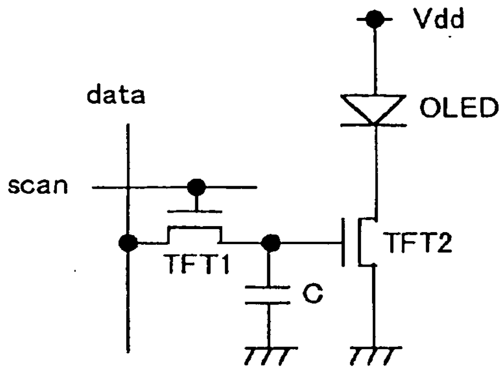
A circuit diagram of a modification of the embodiment of Fig. 14.

[Description of References]

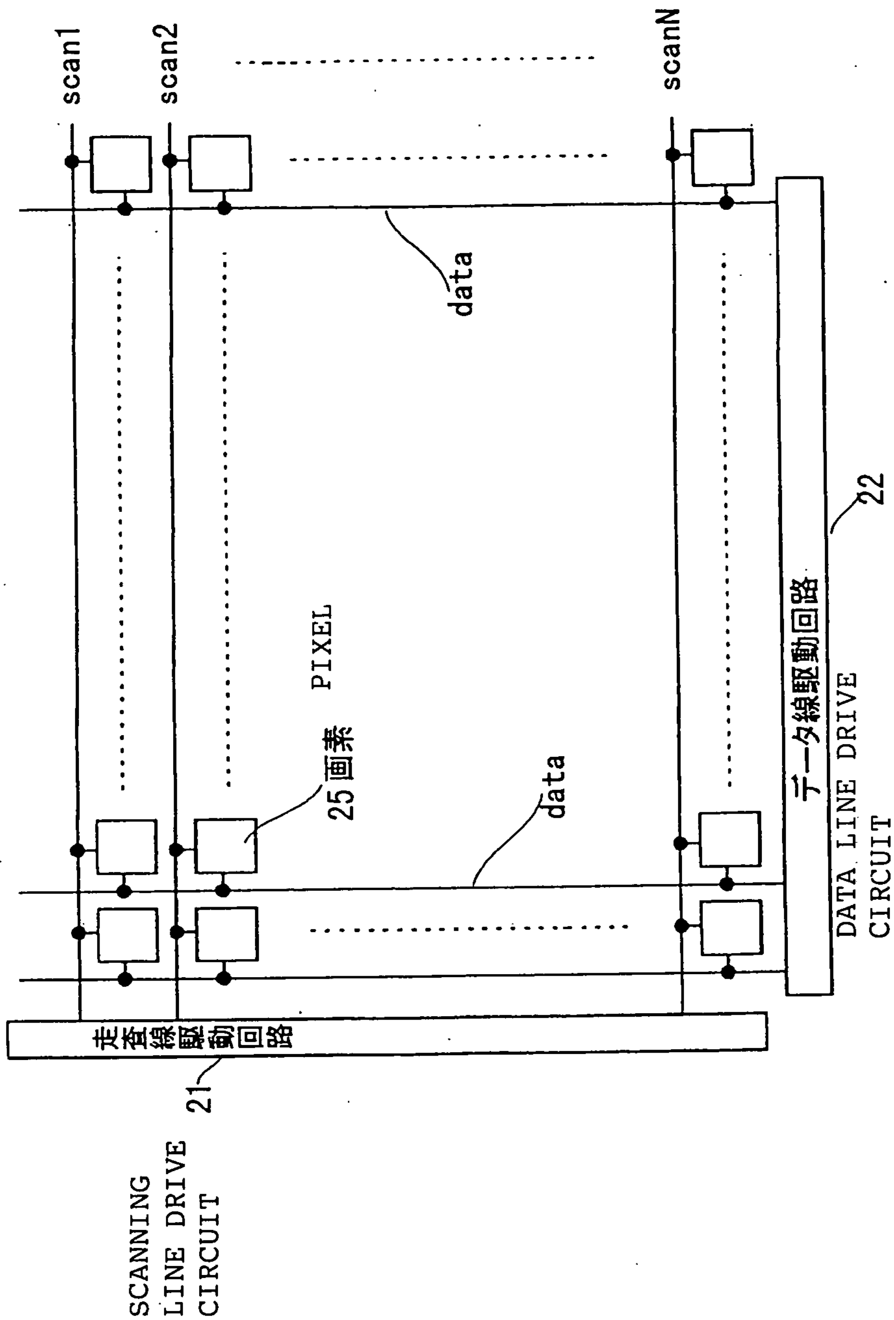
OLED... light emitting element, TFT1...conversion use thin film transistor, TFT2... drive use thin film transistor, TFT3... fetch use thin film transistor, TFT4... switch use thin film transistor, C... holding capacitor, CS... current source, SCAN-A... scanning line, SCAN-B... scanning line, DATA... data line, 21... scanning line drive circuit, 22... data line drive circuit, 23... scanning line drive circuit, 25... pixel

【書類名】　図面　(Name of Document) Drawings

【図1】　Fig. 1



【図２】　Fig. 2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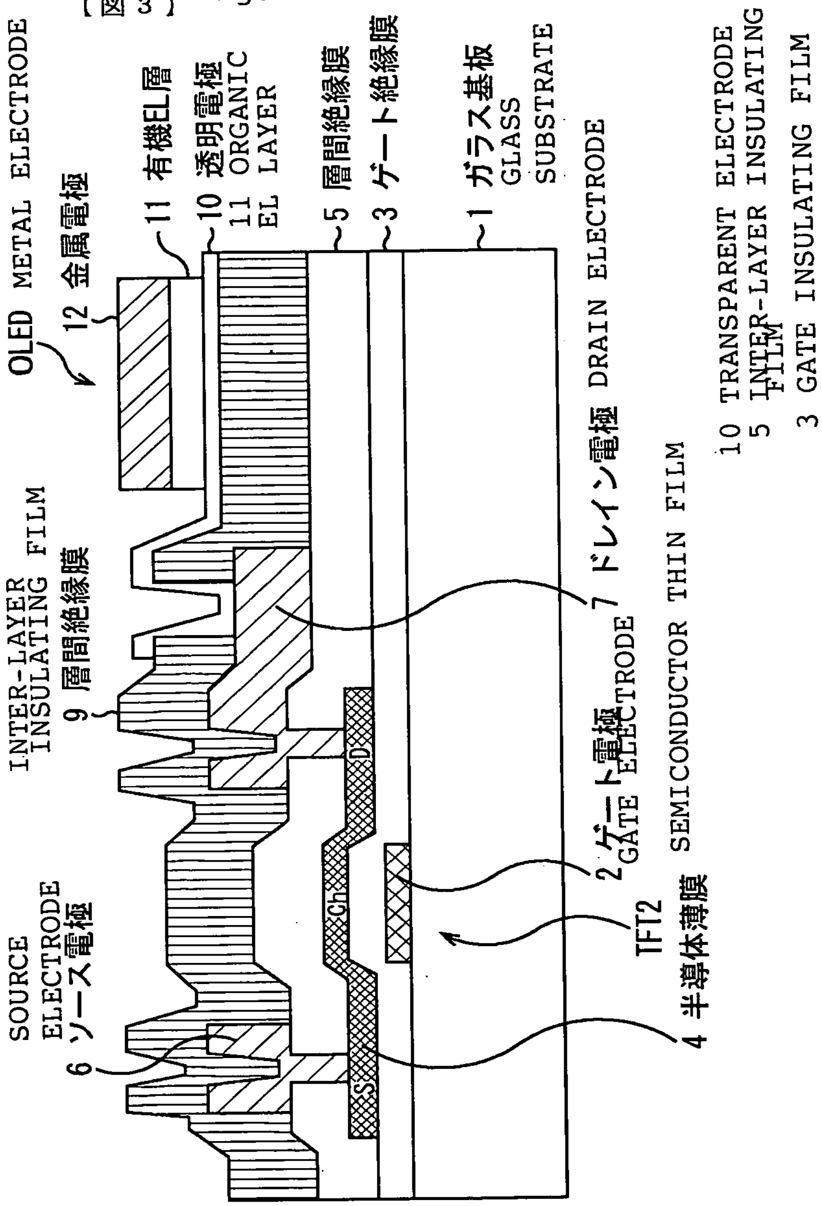
scan2
scanN
data
data
PIXEL
25 画素
22
データ線駆動回路
DATA LINE DRIVE
CIRCUIT
走査線駆動回路
21
SCANNING
LINE DRIVE
CIRCUIT

【図３】 Fig. 3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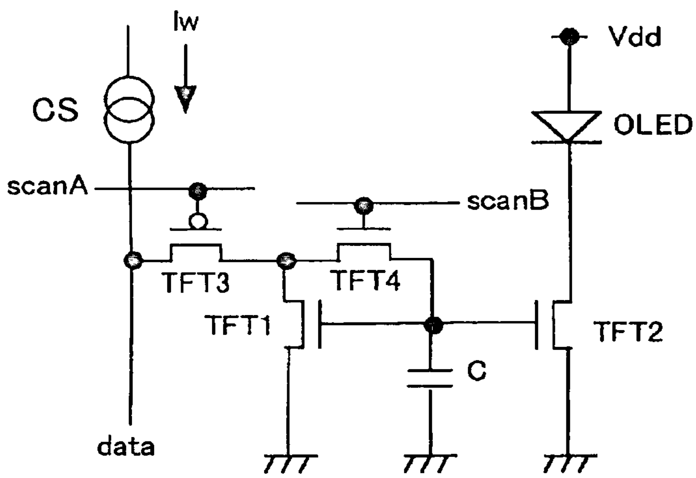
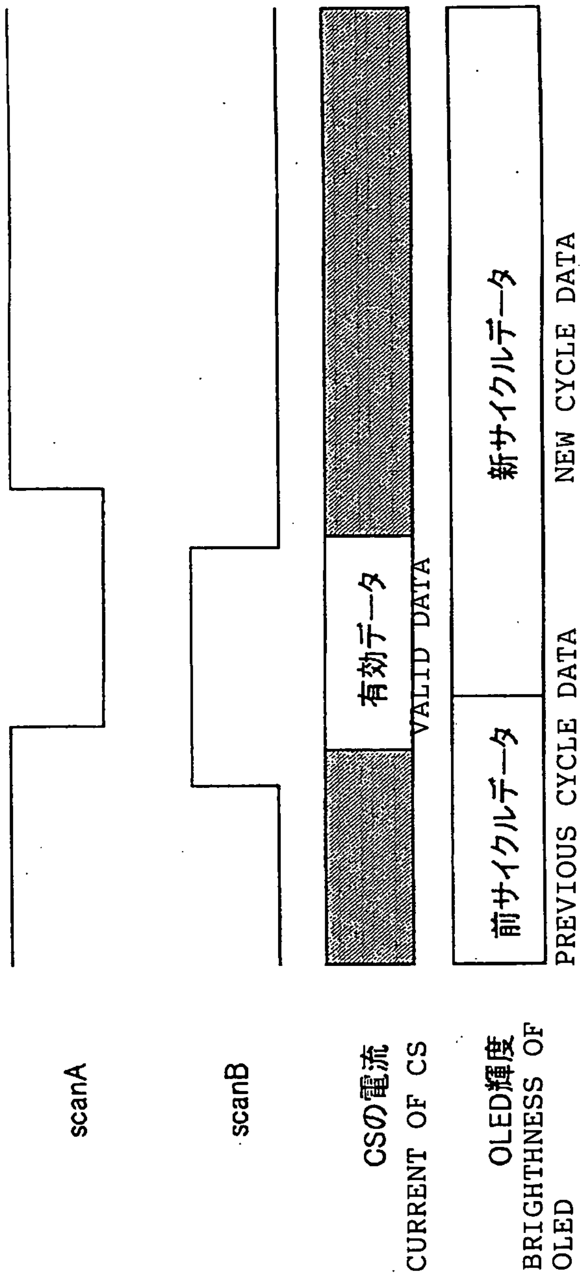
11 ORGANIC EL LAYER
5 層間絶縁膜
3 ゲート絶縁膜
1 ガラス基板 GLASS SUBSTRATE
7 ドレイン電極 DRAIN ELECTRODE
10 TRANSPARENT ELECTRODE
5 INTER-LAYER INSULATING FILM
3 GATE INSULATING FILM
INTER-LAYER INSULATING FILM
9 層間絶縁膜
2 ゲート電極 GATE ELECTRODE
SEMICONDUCTOR THIN FILM
SOURCE ELECTRODE
6 ソース電極
TFT2
4 半導体薄膜
D
Ch
S

【図４】 Fig. 4



【図５】　Fig. 5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scanB
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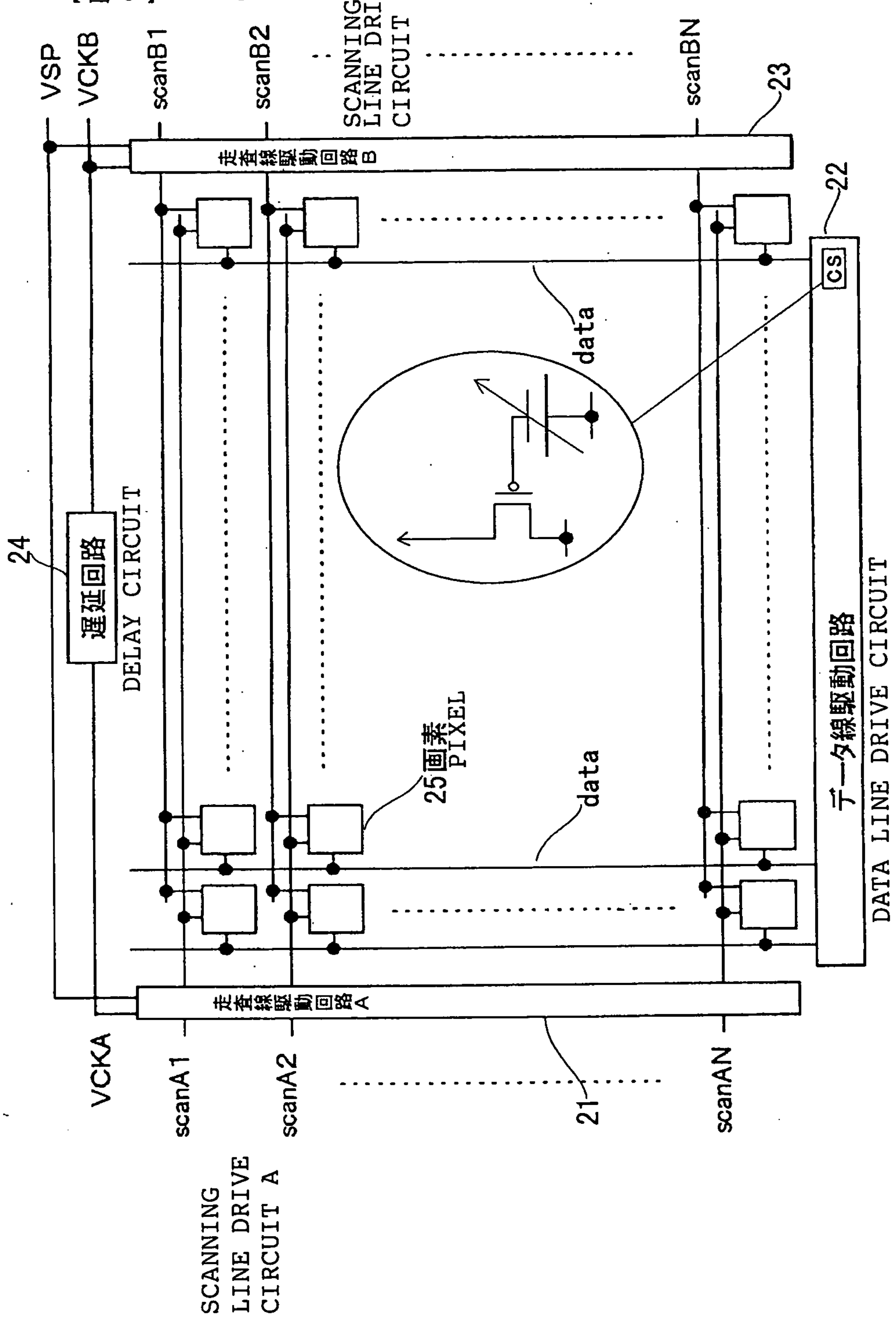
CURRENT OF CS
OLED輝度
BRIGHTHNESS OF OLED
有効データ
VALID DATA
新サイクルデータ
NEW CYCLE DATA
前サイクルデータ
PREVIOUS CYCLE DATA

【図６】 Fig. 6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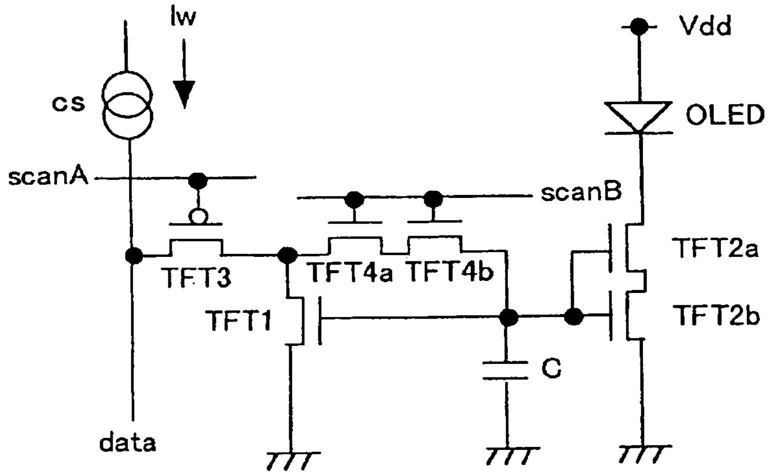
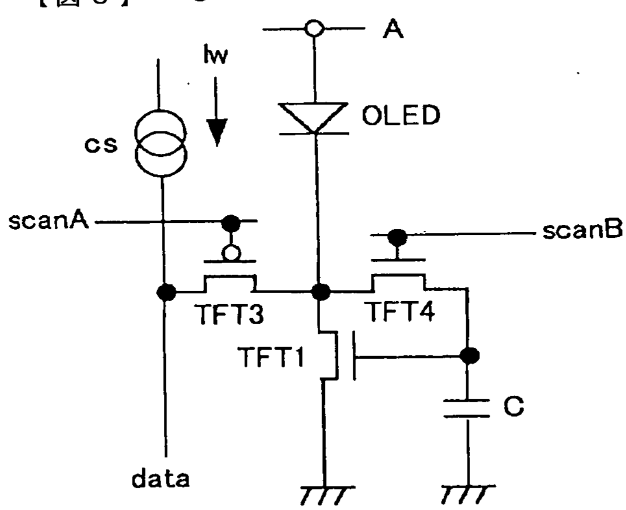
VCKB
scanB1
scanB2
SCANNING LINE DRIVE CIRCUIT B
scanBN
23
走査線駆動回路B
22
CS
data
24
遅延回路
DELAY CIRCUIT
25画素
PIXEL
data
データ線駆動回路
DATA LINE DRIVE CIRCUIT
走査線駆動回路A
VCKA
scanA1
scanA2
21
scanAN
SCANNING LINE DRIVE CIRCUIT A

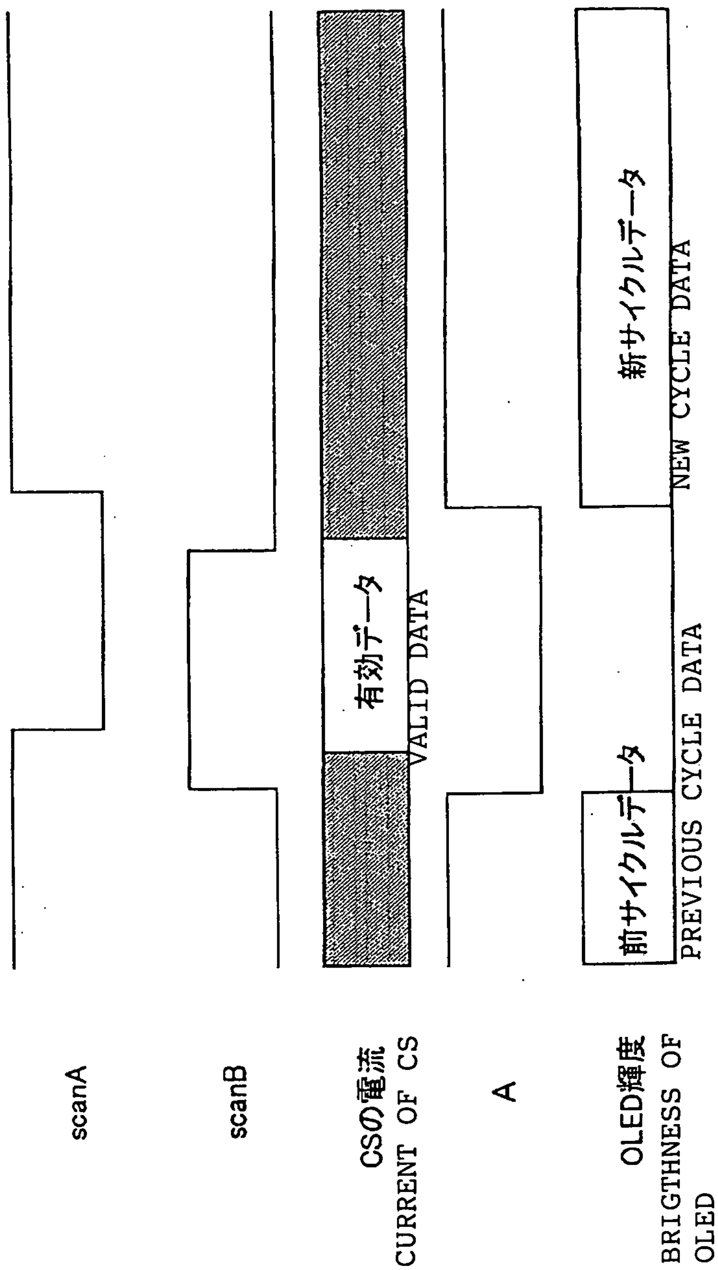
【図７】 Fig. 7



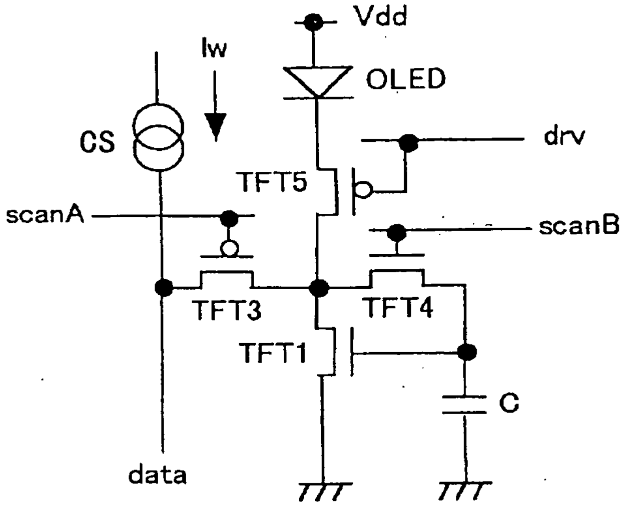
【図８】 Fig. 8



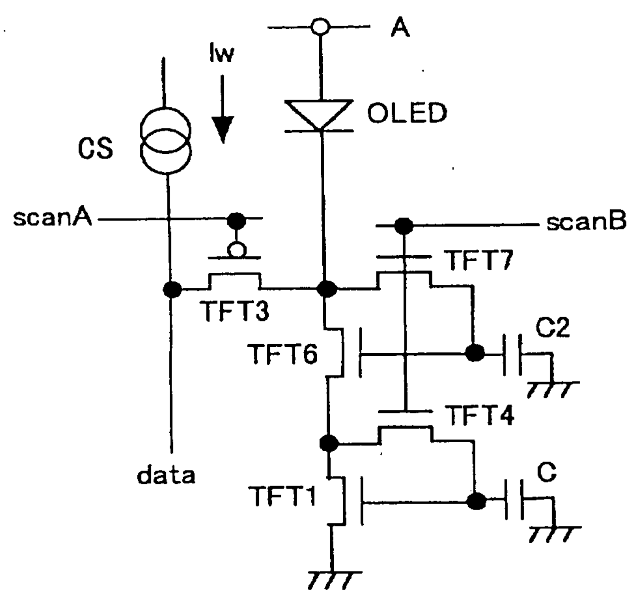
【図９】Fig. 9


scanA
scanB
CSの電流
CURRENT OF CS
A
OLED輝度
BRIGTHNESS OF
OLED
有効データ
VALID DATA
新サイクルデータ
NEW CYCLE DATA
前サイクルデータ
PREVIOUS CYCLE DATA

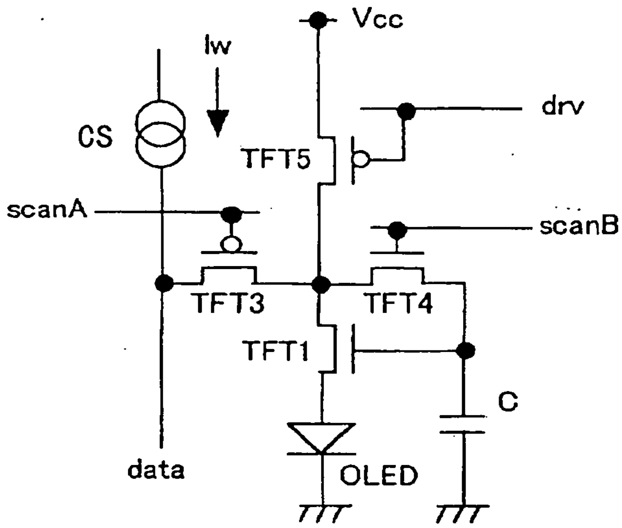
【図１０】 Fig. 10



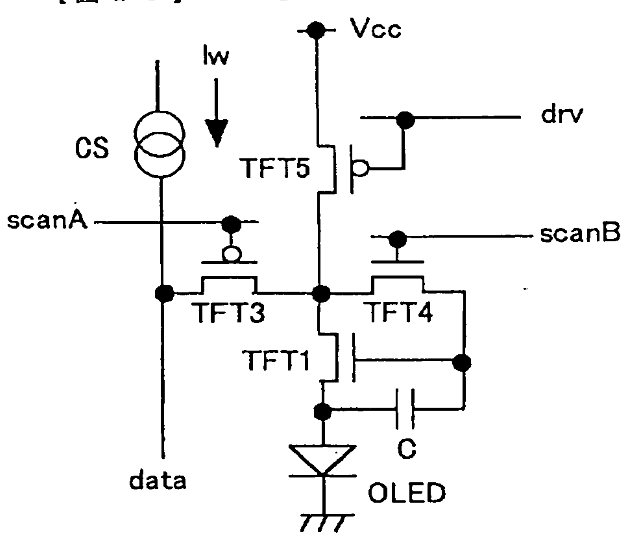
【図１１】 Fig. 11



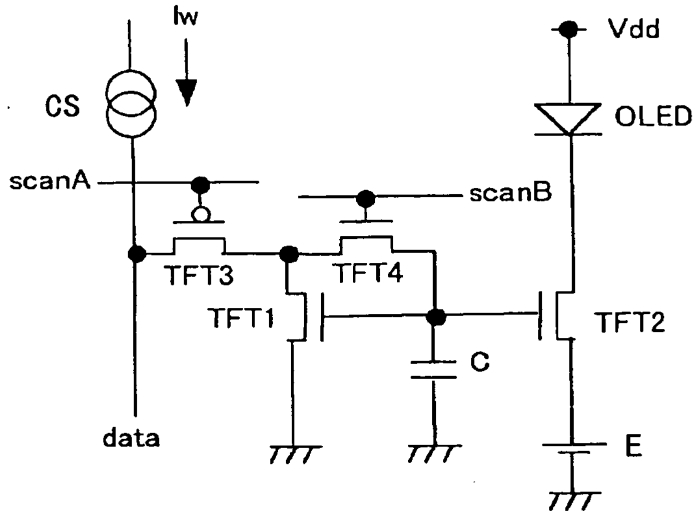
【図１２】　　Fig. 12



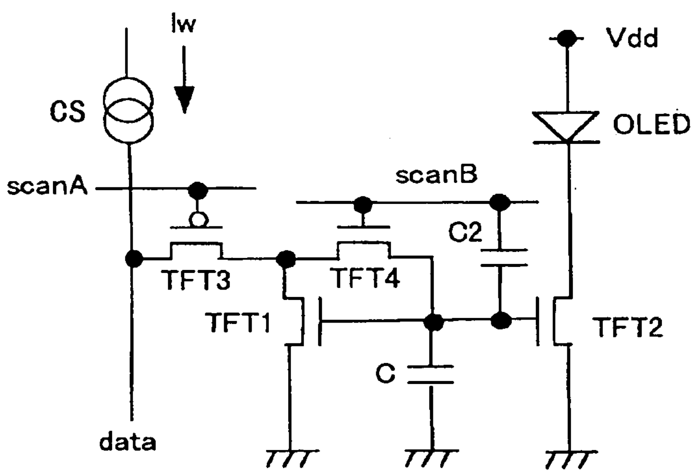
【図１３】　　Fig. 13



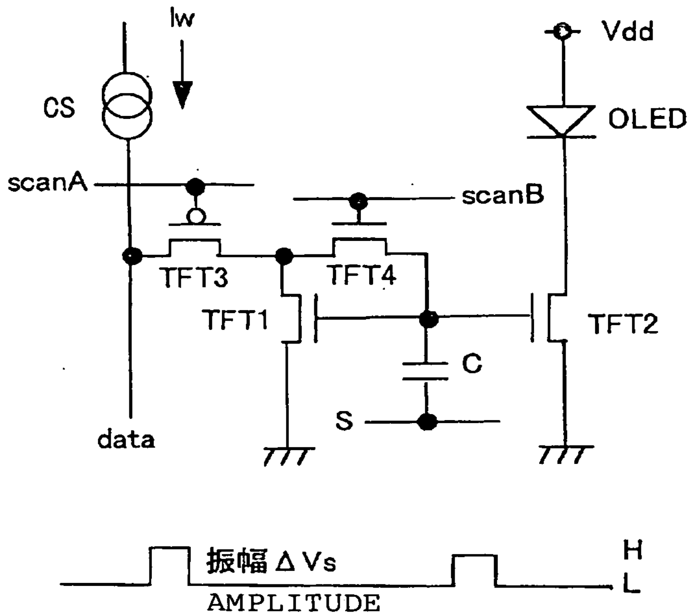
【図１４】　Fig. 14



【図１５】　Fig. 15



【図１６】　Fig. 16


Iw
CS
Vdd
OLED
scanA
scanB
TFT3
TFT4
TFT1
TFT2
C
S
data
振幅ΔVs
AMPLITUDE
H
L

[NAME OF DOCUMENT] Abstract

[ABSTRACT]

[PROBLEM] To provide a display device capable of stably and correctly supplying an intended current to a light emitting element of each pixel without being affected by variations in characteristics of an active element inside the pixel and as a result capable of displaying a high quality image.

[MEANS FOR SOLUTION] Each pixel comprises a receiving use transistor TFT3 for fetching a signal current Iw from a data line DATA when a scanning line SCAN-A is selected, a conversion use transistor TFT1 for once converting a current level of a fetched signal current Iw to a voltage level and holding the same, and a drive use transistor TFT2 for passing a drive current having a current level in accordance with the held voltage level through a light emitting element OLED. The conversion use thin film transistor TFT1 generates a converted voltage level at its own gate by passing the signal current Iw fetched by the TFT3 through its own channel. A capacitor C holds the voltage level created at the gate of the TFT1. The TFT2 passes the drive current having a current level in accordance with the held voltage level through the light emitting element OLED.

[SELECTED DRAWING] Fig. 4